U. S. DEPARTMENT OF AGRICULTURE,
BUREAU OF ENTOMOLOGY—BULLETIN No. 72.
L. O. HOWARD, Entomologist and Chief of Bureau.

INFORMATION CONCERNING THE NORTH AMERICAN FEVER TICK,

WITH NOTES ON OTHER SPECIES.

BY

W. D. HUNTER AND W. A. HOOKER.

ISSUED NOVEMBER 2, 1907.

WASHINGTON:
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LETTER OF TRANSMITTAL.

U. S. Department of Agriculture,
Bureau of Entomology,
Washington, D. C., June 19, 1907.

Sir: I have the honor to transmit herewith a manuscript prepared by Messrs. W. D. Hunter and W. A. Hooker of this Bureau. The manuscript is a study of the life history and habits of the North American fever tick, together with notes on other species. The work upon which this bulletin is based was begun in July, 1905, after practically all of the directors of the southern experiment stations had brought to the attention of this Bureau the necessity of additional work on the important parasite which transmits Texas or splenetic fever of cattle. Prof. H. A. Morgan, director of the Tennessee Experiment Station, has given valuable advice during the progress of the work. The paper contains information of great value in the practical work of tick eradication. I therefore recommend that it be issued as Bulletin No. 72 of this Bureau.

Respectfully,

C. L. Marlatt,
Acting Chief of Bureau.

Hon. James Wilson,
Secretary of Agriculture.

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INTRODUCTORY.

It is safe to state that no more important problem than the eradication of the cattle tick (*Margaropus*[a] *annulatus* Say) confronts the farmers of any country. Not only the cattle-raising industry, but the whole economic condition of a large section of country is affected. The tick, without any but the most limited power of locomotion, and for all practical purposes dependent upon cattle for its existence and dissemination, presents a problem in eradication of a hopeful nature. Cattle are under the control of man. Therefore, the problem is quite different from that involved with other pests, like the boll weevil, which by flight spread over large areas of land. In the one case absolute eradication is possible and in the other it is out of the question. In fact the possibility of the total extermination of the tick in this country is by no means visionary. It was foreseen originally, probably, by Dr. Cooper Curtice, who wrote as follows in 1896: "I look most eagerly for the cleansing of even a certain portion of the infected territory under the direct intention of man, for it opens the way to pushing the tick back to the Spanish Isles and Mexico, and liberating cattle from disease and pests and the farmer from untold money losses. Let your war cry be, Death to the ticks."[b]

In view of these facts it is evident that the most complete knowledge of the habits and life history of the tick is of the utmost importance. All means of eradication must depend upon such knowledge, and improvements in present methods must depend upon additional information regarding the tick. Dr. Cooper Curtice, who will be quoted frequently, because he has been among the foremost in the study of the problem, has written as follows: "To the scientist studying the tick to learn its life history, habits, form, and anatomy,

[a] Neumann has shown that the generic name Boophilus of Curtice must, in obedience to the zoological law of priority, fall as a synonym of the earlier name, Margaropus of Karsch.

[b] Journ. Comp. Med. and Vet. Archives, Vol. XVII, p. 655.

the fact that these animals are pests to the stockman throughout the greater part of the year is of very little importance, while the latter cares little about such matters if he can only learn how to rid his cattle of them. Yet it is only by learning the life history that remedies to prevent them can be applied intelligently, and the fact that the knowledge attained is of practical value adds a double interest to their study."[a]

In view of the evident importance of the work it is surprising that so little has been done in this country. In 1892, about a year previous to the issuance of Smith and Kilborne's epoch-making bulletin demonstrating the tick transmission of fever, Dr. Cooper Curtice published the first data regarding the life history of the cattle tick as Bulletin 24 of the Texas Agricultural Experiment Station. It was accompanied by excellent illustrations. The value of this work will be understood from the fact that it was of a pioneer character, and that all subsequent work has depended upon it. Nevertheless, it was of a preliminary nature and merely outlined matters that must eventually receive the most careful investigations.

Prof. H. A. Morgan, principally in bulletins 51 and 56 of the Louisiana Experiment Station, has added greatly to our knowledge of the cattle tick as well as other species. His work has such practical bearings that it has been the chief indication of the value of life-history studies in pointing out successful methods of eradication. Recently Messrs. Wilmon Newell and M. S. Dougherty, of the Louisiana crop-pest commission, have published a valuable contribution which still further shows how every fact relating to the tick can be utilized in combating it.

The above are the principal publications by American workers. There are many others which also contribute important facts. Among these are Connaway's, Schroeder and Cotton's, Ransom's, and others. In other countries excellent work has been done on related forms. In South Africa Prof. C. P. Lounsbury has made scholarly studies of *Margaropus* (*Boophilus*) *decoloratus* and many other species. In Argentina, Dr. F. Lahille has recently published the results of some of the most exhaustive work on ticks that has been done. These works, with others, are listed in the bibliography at the end of this bulletin.

Notwithstanding the studies that have been conducted in this country, it must be stated that our knowledge of the tick is far short of what it should be. There is a lack of knowledge of local variations, due to climatic influences, as well as such matters as dissemination. To supply this deficiency, the Bureau of Entomology, in cooperation with the officers of several experiment stations, has undertaken a

[a] Tex. Agr. Exp. Sta. Bul. 24, p. 238.

careful study of the tick. Some of the results of practical bearing are given in the following pages and others will be published from time to time.

The writers desire to express their thanks to Prof. H. A. Morgan, director of the Tennessee Agricultural Experiment Station, for many most valuable and courteous suggestions in the course of this work. He has turned over to the writers many of his original notes and has generously assisted in numerous other ways.

LOSSES OCCASIONED BY THE CATTLE TICK.

Undoubtedly the popular idea of the damage caused by the cattle tick concerns itself with the actual death of cattle from the disease transmitted by the tick. Although this is a very important matter and would fully justify the most energetic attempts toward the eradication of the tick, it is really unimportant in comparison with the other losses. Mr. August Mayer, a practical cattle breeder of Shreveport, La., and Dr. J. R. Mohler, of the Bureau of Animal Industry of this Department, have made most careful, comprehensive estimates of the losses caused by ticks. The following summary is taken largely from their writings:

1. Loss by death from disease in young animals and those removed from temporarily tick-free localities (as, for instance, in cities) to places where they become infested. The enormous loss under this heading will be understood when it is recalled that every bovine animal in the tick area must suffer an attack of fever if it becomes infested with ticks. In an instance that came to the attention of the writers, 39 out of 40 calves dropped in a city died of tick fever when removed to an infested pasture.

2. Loss in weakened condition and stunted growth caused by the fever.

3. Loss by gross tick infestation. At the present time (March, 1907) hundreds of cattle in south Texas are dying from gross infestation resulting from a mild winter. In extreme cases, Mr. Mayer estimates that as many as 200 pounds of blood may be withdrawn from the host during a single season. This makes a gain in weight impossible even in the best of pastures. Moreover, Prof. H. A. Morgan and other observers believe that gross infestation and the consequent general debility induce acute attack of fever even in animals ordinarily immune.

4. The tick makes hazardous the importation of pure-bred cattle. This prevents the upbuilding of southern cattle and at the same time largely deprives the northern breeder of a market that he should have. Moreover, the inability of the southern breeder to exhibit his stock in

the north and of the northern breeder to exhibit his in the tick area is a handicap, the importance of which will be readily seen.

5. The necessary restrictions in the shipping of southern cattle also handicap the breeder and affect the price.

6. The maintenance of the quarantine involves considerable annual expense for the protection of the cattle owners north of the line.

7. Minor losses may be grouped as follows: (*a*) In Texas, especially, the tick induces the attack of the screw-worm fly (*Chrysomyia macellaria* Fab.); (*b*) there seems to be, as pointed out by Mr. Mayer, a considerable interference with the fecundity of infested cows; (*c*) the railroads are put to the expense of disinfecting cars and maintaining separate pens and the stockman to the expense of dipping—items which react on the price that southern cattle bring.

All the losses that have been mentioned total approximately $100,000,000 each year. At present the loss, as indicated by Doctor Mohler, amounts annually to at least 10 per cent of the value of the cattle. The quality of the animals is the lowest and the loss is greatest in the regions where the natural conditions without the tick should produce the finest cattle with the least loss. But the damage may be better expressed by the statement that the tick makes profitable production practically impossible in the South. Any successful system of agriculture must rest upon a diversification of crops, and this, in turn, depends upon animal husbandry to maintain the fertility of the soil. Therefore, until the tick is eradicated or placed under control, a rational system of agriculture in the infested area is out of the question, and that achievement would mean almost as much to the North as to the South.

THE LIFE HISTORY OF TICKS IN GENERAL.

The following general statement regarding the life history of ticks is taken from Salmon and Stiles:[a]

Ticks are temporary parasites, attacking mammals, birds, and reptiles. They do not appear to be so strictly confined to certain hosts as do parasites in general. Still, this may be more of an apparent than a real rule. Certain it is that, although a given tick may be found occasionally on animals which are very dissimilar (dog ticks have, for instance, been found on snakes), still the various species show a decided predilection for certain hosts.

The parasites copulate during the period of parasitism[b] and suck the blood from their hosts. The female grows to a large size and eventually drops to the ground and

[a] Seventeenth Ann. Rept. Bureau of Animal Industry, U. S. Dept. Agric., p. 398.

[b] This is not invariable. *Amblyomma americanum* sometimes copulates soon after the second molt, but before it has gained a host. It is likely that other species also occasionally do so.—W. D. H. and W. A. H.

lays numerous eggs, which are usually more or less clustered together. The larva upon hatching possesses three pairs of legs, the fourth pair being added during the first molt. Either the hexapod or the octopod form may attack its host.

From the foregoing it will be seen that the cattle tick, like other ticks, passes through the following stages: Egg, larva (six-legged form), nymph, and adult.

The eggs are nearly round, dark brown in color, and deposited in large masses, held together by the gummy secretion with which the female coats each egg as it is deposited. The next stage, known as the seed tick, differs remarkably from the later stages in the fact that six instead of eight legs are present. The stigmata are located between the second and third coxæ, just anterior to the third coxæ, and problematic indications are seen between the first and second coxæ. No distinct genital or anal opening can be seen in this stage. The anterior legs are much larger than the others. They are waved violently through the air when the seed ticks are disturbed either by the approach of a host or in any other way. After some time the seed tick molts and the next, or nymphal stage, is provided with eight legs. The absence of the genital opening will differentiate this stage from the following one. Ticks in the nymphal stage are frequently referred to in the South as "yearling ticks." After a second molt the adult form is reached. Copulation then takes place, and after engorgement the female drops to the ground for the purpose of depositing eggs.

THE LIFE HISTORY OF THE CATTLE TICK.

As pointed out by Morgan the most important fact about the cattle tick (*Margaropus annulatus* Say), from the standpoint of practical control, is that the time of development on the animal is always shorter than the total of the preoviposition, oviposition, and incubation periods. This gives the farmer an opportunity to free his cattle and pastures of ticks by the same process of rotation. As a foundation for the surest and most economical procedure an accurate knowledge of the variations of the periods in the life history of the tick under different conditions is absolutely essential. Our effort in this bulletin is in a measure to supply this information. The work has been principally to obtain data necessary in the pasture eradication and feed-lot systems of eradication. We have consequently studied the development of the tick both during its existence on the animal, by means of a steer procured for that purpose, and during its life, under various conditions, when not attached to the host.

PERIOD PREVIOUS TO OVIPOSITION.

The cattle tick, like other species, passes through a distinct period between the time of dropping from the host and the beginning of oviposition. When the tick drops, the eggs are not ready to be deposited, but must pass from the ovary through the oviduct. (See fig. 1.) Thus there is a definite physiological basis for a period which has a very practical bearing on plans of eradication that depend upon a knowledge of the exact time to be allowed in removing cattle from one inclosure to another. Lahille has used the term "prootoquie" for this period, but we shall refer to it merely as the preoviposition period.

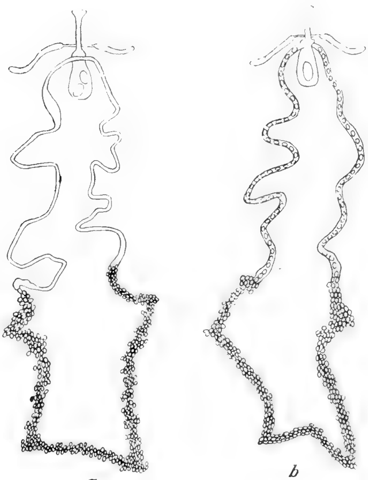


FIG. 1. Genital apparatus of *Margaropus microplus*: *a*, Position of eggs at time of dropping of tick from host; *b*, position of eggs when oviposition begins. Highly magnified (redrawn from Lahille).

As will be seen from Table I the preoviposition period ranges from 2 to 40 days, depending upon temperature. In the summer it averages between 3 and 4 days, and in winter over 20 days.

It might be supposed that the data in the table referred to show a preoviposition period longer than normal on account of the removal of the ticks artificially. However, only ticks about to drop were selected, and repeated tests with ticks actually dropped showed that the method followed gives the natural preoviposition period.

OVIPOSITION PERIOD.

As will be seen from Table I, the period occupied in oviposition ranges from 6 to 70 days, depending upon the temperature. In the summer it averages 10 or 11 days, while in the winter it is two or three times as long.

TABLE I.—*Oviposition of Margaropus annulatus, July, 1905, to July, 1906, at Dallas, Tex.*

When collected.	Number of ticks.	Preoviposition period.			Oviposition period.			Period from dropping to end of oviposition.			Number of eggs per tick.		
		Maximum.	Minimum.	Weighted average.	Maximum.	Minimum.	Weighted average.	Maximum.	Minimum.	Weighted average.	Maximum.	Minimum.	Weighted average.
1905.		*Days.*	*Days.*	*Days.*	*Days.*	*Days.*	*Days.*	*Days.*	*Days.*	*Days.*	*Eggs.*	*Eggs.*	*Eggs.*
July 21	18	3	2	2.9	13	6	8.2	14	8	11.0	3,806	515	1,185
Aug. 3	4	5	3	3.5	11	7	9.0	13	11	11.8	2,228	1,466	1,971
Sept. 18	10	4	3	3.4	18	12	15.0	20	14	17.0	......	......	......
Sept. 27	6	3	3	3.0	19	19	19.0	21	21	21.0	3,875	2,365	2,576
Oct. 12	15	6	4	5.1	44	21	30.7	48	21	32.0	2,311	694	1,795
Nov. 6	15	15	10	11.9	64	21	39.9	79	33	50.8	2,689	805	1,891
Dec. 6	14	41	21	28.6	70	20	42.6	90	55	71.0	3,946	464	1,779
1906.													
Feb. 6	8	39	18	21.8	47	8	29.8	58	26	50.5	2,134	147	695
Feb. 21	9	40	13	18.7	41	30	38.9	53	38	47.8	3,496	10	2,009
Mar. 23	10	10	9	9.8	29	12	23.4	38	21	30.2	2,437	1,118	1,941
Apr. 6	10	6	3	4.8	25	17	21.8	30	20	25.7	2,260	1,281	1,658
Apr. 20	10	6	5	5.4	18	11	15.6	22	16	20.0	3,412	2,197	2,891
May 4	10	10	6	7.8	17	11	14.6	24	18	21.4	2,676	1,701	2,251
May 22	10	6	4	4.3	15	10	12.6	18	15	16.4	3,180	1,391	2,250
June 5	10	5	3	3.5	13	9	10.9	15	12	13.4	2,881	152	1,802
June 20	10	4	3	3.5	14	9	11.7	16	8	14.2	2,467	843	1,950
July 2	10	5	3	3.9	14	9	11.0	16	12	13.9	2,292	1,135	1,837
July 13	10	4	3	3.1	13	7	10.4	13	8	12.5	2,397	1,666	2.068
Total	189	......	......	......	......	......	......	......	......	......	......	......	32,499
Average	......	......	......	......	......	......	......	......	......	......	......	......	1,911.7

From Table I the following important, practical data are obtained:

1. The preoviposition period ranges from about 3 days in summer to as many as 28 days in winter.
2. The oviposition period ranges from between 8 and 9 days in summer to 42 days in winter.
3. The total period from dropping to the end of oviposition ranges from 11 days in summer to 71 days in winter.

It should be noted that Table I gives the total period from dropping to the end of oviposition based upon the weighted averages of the preoviposition and the oviposition periods. Therefore the maximum total period may be somewhat longer than indicated, as, for instance, in cases where either the preoviposition or the oviposition for some reason are prolonged beyond the average.

EGG STAGE.

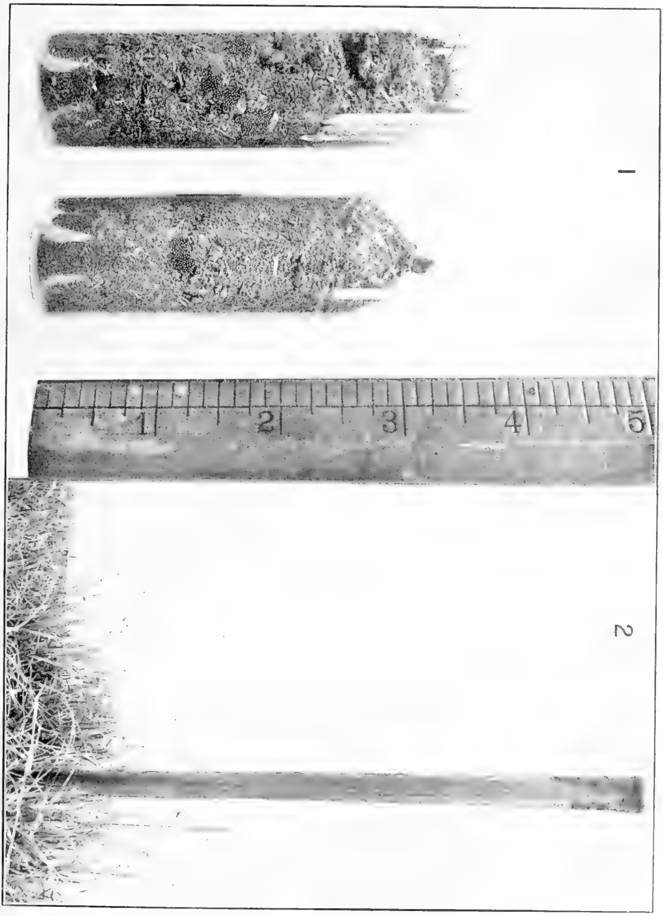
The eggs are generally elliptical, but vary in shape on account of pressure and drying. In color they are at first honey-yellow, but soon change to a deep yellowish brown. They are shiny and smooth. The average size in a lot of 10, measured by a micrometer, was 0.54 by 0.42 mm. About the middle of the incubation period in many species a whitish spot appears on the eggs and becomes more conspicuous as the time for hatching approaches. This spot is

located toward one end and seems to be due to the excretion of the embryo. In *Margaropus annulatus* it is very conspicuous and is a certain indication of viability.

The act of oviposition is most interesting. This process was referred to by Dr. Cooper Curtice.[a] An analogous operation in *Ixodes ricinus* has recently been carefully described and illustrated by Wheler,[b] and was earlier noted by Lewis.[c] One of our associates, Mr. R. A. Cushman, has observed the operation. The following description is based upon his notes:

When oviposition is about to take place the capitulum is bent downward toward the genital aperture. This exposes a delicate, viscid membrane between the capitulum and the scutum. The membrane becomes distended and is projected out over the capitulum in two rounded lobes, practically covering it. This process is repeated several times before the egg is finally ejected, the membrane being extruded and retracted alternately while the capitulum is lowered and raised. Finally the white, membranous ovipositor is extended, turning inside out, until it touches the distended membrane. The capitulum is now completely hidden. As soon as the ovipositor and membrane have come in contact the former slowly recedes, leaving the egg adhering to and partially enveloped by the membrane. The egg remains in this position for a varying length of time. Then the membrane is withdrawn, rolling the egg along for a short distance on the dorsal surface of the capitulum. At the same time the capitulum is raised. Then the processes of distention and contraction of the membrane and lowering and raising of the capitulum are repeated several times, the egg being finally completely coated by the viscid substance from the membrane and being finally pushed back and deposited on the anterior edge of the scutum. Each egg is laid in this manner, the tick backing slowly away and leaving the mass of eggs in front of her. The actual time consumed by the tick in laying a single egg is about 30 seconds, while the removal of the egg and the resting period consume from one to several minutes, a much longer resting period being taken at intervals between lots of from 10 to 50 eggs. It has been impossible for us with the means at our command to demonstrate the "paired, racemose glands" of the membranous sac referred to by Curtice. As far as we have been able to see, the substance with which the eggs are coated is secreted from numerous minute glands scattered over the surface.

[a] Tex. Agr. Exp. Sta., Bul. 24, p. 242.
[b] Journ. Agric. Sci., 1906, p. 405.
[c] Proc. Roy. Micros. Soc., 1892.



THE NORTH AMERICAN FEVER TICK.

Fig. 1.—Eggs of *Margaropus annulatus* deposited under stable litter. Fig. 2.—Seed ticks of Margaropus bunched on grass and stake. (Original.)

THE NORTH AMERICAN FEVER TICK.

Fig. 1.—Steer used in experimental work. Fig. 2.—Arrangement for obtaining data on incubation. (Original.)

In the manner described a mass of eggs grows steadily in front of the tick, while its body becomes correspondingly smaller as the process proceeds. The gummy secretion holds the eggs together so that the mass looks not unlike a large accumulation of minute brown beads.

The number of eggs deposited varies greatly with the size of the female. The highest number recorded in our experiments was 3,806.[a] The average of 189 ticks under various conditions was 1911.7, and this probably very closely approximates the average under natural conditions. The daily average, of course, varies also. The maximum is generally reached from 7 to 9 days after deposition begins. The highest number for any 24-hour period was 826. The average for 20 ticks was 144.

INCUBATION.

Most important means of control of the cattle tick depend upon taking advantage of the fact that eggs remain on the ground for a considerable time before hatching. Provided there are no seed ticks present, it is perfectly safe to allow cattle in areas in which ticks may be dropped from them, as, for instance, in fields under cultivation for one crop season, if the animals are removed before hatching takes place. It will be seen that this has an important bearing on the process of relieving cattle of ticks by placing them for limited periods in different tick-free inclosures. Accordingly we have made an especial effort to obtain data regarding the period occupied in incubation under different conditions and in different seasons.

In 1905 a number of experiments to determine the length of the incubation period were conducted, the eggs being placed in paper pill boxes. Subsequent work showed that this arrangement gives more rapid development of the embryo than takes place under normal conditions. Especially is the period shortened when an abundance of moisture is furnished. In these experiments in July and August the eggs hatched in from 17 to 21 days, and during September in from 25 to 44 days. These results are of value only in showing how the incubation period may be shortened under extreme conditions, which must rarely or never occur in nature.

No eggs deposited in October, 1905, hatched before April 10, 1906, a period of over 170 days.

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[a] The greatest number found by H. A. Morgan was 3,198 (La. Agr. Exp. Sta., Bul. 51, p. 242), but Newell and Dougherty record 4,124 in one instance (La. Crop Pest Comm., Circ. 10, p. 23).

In 1906 a more extended series of experiments was instituted. In the first series, consisting of 59 lots deposited from February 20 to September 21, eggs were kept in pill boxes. As has been pointed out, this method accelerates incubation further than natural conditions are likely to. The following is a summary of the results of these experiments:

Eggs deposited in March hatched in 74 days.
Eggs deposited in April hatched in 43 to 53 days.
Eggs deposited in May hatched in 24 to 33 days.
Eggs deposited in June hatched in 20 to 22 days.
Eggs deposited in July hatched in 19 to 22 days.
Eggs deposited in August hatched in 19 to 21 days.
Eggs deposited in September hatched in 23 to 154 days.
Eggs deposited October 1–7 hatched in 135 to 139 days.
Eggs deposited October 15 and later have not hatched to date (February 20, 1907).

In the second series of experiments relating to incubation conducted in 1906 a special effort was made to provide conditions that would give approximately the same period that must occur under normal conditions. (See Table II.) To do so some eggs were placed on soil in open-bottom glass tubes in the open air (see Pl. II, fig. 2) and shaded for a portion of the day. Others placed under the same conditions were exposed to the sun at all times. In the third series the eggs were located in an outdoor thermometer shelter where they were protected from sun and rain. The separate lots consisted of several hundred eggs. They were deposited by different females in the laboratory and placed together for the observations under consideration. In this way a large number of eggs deposited within the same 24-hour period was obtained. It is supposed that these conditions approximate closely to those which surround the great majority of eggs in pastures. The following is a summary of the data contained in the table:

Eggs deposited in April hatched in from 39 to 54 days.
Eggs deposited in May hatched in from 27 to 33 days.
Eggs deposited in June hatched in from 21 to 28 days.
Eggs deposited in July hatched in from 22 to 26 days.
Eggs deposited in August hatched in from 23 to 32 days.

In September eggs deposited prior to the 18th hatched in from 23 to 76 days. Eggs deposited after September 18 have not hatched up to February 20, with but two exceptions. These were eggs deposited October 3 and October 7, which began to hatch on February 18. These eggs were placed in such a way that they were more exposed to the sun than other lots that have not hatched, deposited before and since the dates mentioned.

TABLE II.—*Period of incubation of Margaropus annulatus at Dallas, Tex., 1906, under various conditions.*

Eggs deposited.	Hatching.	Minimum incubation period.	Eggs deposited.	Hatching.	Minimum incubation period.
		Days.			*Days.*
Apr. 13	June 5	[a] 54	Aug. 12	Sept. 8	[a] 28
Apr. 14	May 30	[a] 47	Aug. 14	Sept. 6	[b] 24
Apr. 15	May 31	[a] 47	Aug. 18	Sept. 9	[b] 23
Apr. 27	June 4	[a] 39	Aug. 18	Sept. 18	[a] 32
May 13	June 14	[a] 33	Aug. 19	Sept. 10	[b] 23
May 15	June 12	[a] 29	Aug. 19	Sept. 11	[c] 24
May 28	June 23	[a] 27	Aug. 22	Sept. 13	[a] 23
May 30	June 26	[a] 28	Aug. 22	Sept. 14	[c] 24
May 31	June 27	[a] 28	Aug. 24	Sept. 16	[b] 24
June 9	July 5	[a] 27	Aug. 28	Sept. 20	[b] 24
June 10	July 5	[a] 26	Aug. 28	Sept. 21	[c] 25
June 11	July 7	[a] 27	Aug. 28	Sept. 23	[a] 27
June 21	July 18	[a] 28	Sept. 1	Sept. 23	[c] 23
June 22	July 14	[b] 23	Sept. 1	Sept. 24	[b] 24
June 24	July 16	[a] 23	Sept. 1	Sept. 27	[a] 27
June 24	July 16	[b] 23	Sept. 2	Sept. 26	[c] 25
June 30	July 20	[b] 21	Sept. 9	Oct. 7	[c] 29
July 1	July 22	[a] 22	Sept. 9	Oct. 10	[b] 32
July 20	Aug. 10	[b] 22	Sept. 9	Oct. 15	[a] 37
July 20	Aug. 14	[a] 26	Sept. 14	Oct. 24	[c] 41
July 22	Aug. 14	[c] 24	Sept. 14	Oct. 26	[b] 43
July 31	Aug. 22	[b] 23	Sept. 14	Nov. 5	[a] 53
July 31	Aug. 22	[c] 23	Sept. 18	Dec. 2	[b] 76
July 31	Aug. 23	[a] 24	Sept. 18	Dec. 2	[a] 76
Aug. 11	Sept. 4	[b] 25	Sept. 26	Feb. 20	[b] 148
Aug. 12	Sept. 3	[c] 23			

[a] The eggs were placed in open-bottom test tubes in sand in the open air. They were protected from the direct rays of the sun at all times by a cheese-cloth screen. Up to 11 a. m. they were within the shade of the house.
[b] In open-bottom test tubes in soil exposed to sun at all times.
[c] In open pill boxes outdoors protected from sun and rain at all times.

RELATION OF TEMPERATURE TO INCUBATION.

In the series of experiments just referred to accurate data on temperature were obtained. Standard maximum and minimum thermometers kept in an instrument shelter were used. In Table III the records of temperatures are given together with the average incubation periods for the various lots of eggs under observation during different months. The data show that there is an intimate relation between temperature and the period of incubation. The shortest average minimum incubation period (23.4 days) occurred when the average temperature was highest (80.2° F.). The longest average minimum incubation period (137 days) occurred with the lowest average mean temperature (53.2° F.). Between these extremes there is a graduated correspondence between temperature and incubation.

TABLE III.—*Relation of temperature to period of incubation in Margaropus annulatus at Dallas, Tex., 1905–1906.*

Month deposited.	No. of lots.	Incubation period.			Incubation temperature.					
					Mean.			Total effective.		
		Maximum.	Minimum.	Average.[a]	Maximum.	Minimum.	Average.	Maximum.	Minimum.	Average.
		Days.	*Days.*	*Days.*	°*F.*	°*F.*	°*F.*	°*F.*	°*F.*	°*F.*
1905.										
Sept.	2	56	43	49.5	62.6	62.3	62.4	1,083	840.5	961.8
1906.										
Apr.	4	54	39	46.7	72.6	69.7	70.8	1,475.8	1,139.1	1,286.4
May	5	33	27	29	79.7	73.5	77.6	1,103.2	981.6	1,023
June	8	28	21	24.8	80.5	79.8	80.2	1,046.6	782.7	920.7
July	7	26	22	23.4	80.5	79.8	80.2	962.1	824.3	866.5
Aug.	14	32	23	24.9	79.7	78.9	77.8	1,169.3	826.7	904.4
Sept.	13	154	23	46.2	79.4	54.6	70.7	1,907.9	837.6	1,127
Oct.	2	139	135	137	53.4	53	53.2	1,600.6	1,510.8	1,555.7

[a] Weighted.

It will be noted that the total effective temperature necessary to cause eggs to hatch varies from 866.5° to 1,555.7°. It would be of the greatest practical importance to formulate a rule which, on the basis of effective temperatures, would show the time when eggs will hatch at different seasons of the year. It is probable that the present data are insufficient for this purpose, and special efforts will be made to add to them. However, with the data at present available the following tentative law may be proposed:[a]

When the average daily mean temperature ranges less than 53.2°, at least 1,510.8 degrees of effective temperature must accumulate before hatching will take place. When the mean daily temperature averages from 61.4° to 77.8°, from 840.5 to 1,139.1 degrees of effective temperature will be required for hatching. When the mean daily temperature averages higher than 80°, between 782.7 and 824.3 degrees of effective temperature must be accumulated before hatching will take place.

It is not our purpose to advise an attempt at the practical application of this rule at the present time, but it is supposed that such practical application can be ultimately made. To do so it would only be necessary for the stockman to have a set of self-recording maximum and minimum thermometers, such as can be purchased for $3. Or the data might be obtained from the nearest Weather Bureau station. By either of these means the average daily temperature could be easily obtained. By summing up the daily effective temperatures—that is, the number of degrees above 43—the stockman, by reference to the minimum amount of accumulated effective temperature necessary for hatching with various average daily temperatures, could determine at least within certain limits what time

[a] This rule, of course, may not apply in rare cases in which eggs are deposited where they will be subject to artificial heat rather than to weather temperature, as in manure piles. It will apply, however, to the great majority of pasture conditions throughout the infested area.

it would be necessary to remove cattle from pastures in which tick eggs might be to avoid danger of infestation by seed ticks. Possibly a more feasible application would be the collection of the necessary data from many localities by the State entomologists and the publication of predictions based upon them from time to time.

A seasonal arrangement of our data for 1905 and 1906 shows the following:

Eggs deposited in June, July, August, and up to September 15 require from 824.3 to 840.5 degrees of accumulated effective temperature for hatching.

Eggs deposited from September 16–30, in October, and in later fall and winter months, require an accumulated effective temperature of from 837.6 to 1,510.8 degrees.

Eggs deposited in April and May require from 981.6 to 1,139.1 degrees.

Naturally an arrangement by months as above must be defective, since no two seasons are exactly alike. The only accurate method must be based upon a knowledge of the temperatures that are accumulating in any particular season.

EFFECT OF HEAT AND COLD ON EGGS.

In experiments to determine the effects of heat upon eggs a continuous temperature of 100° was maintained by means of an incubator. The period of application of heat was 15 days. In one series no moisture was provided, and in this case no hatching took place. In another series in which abundant moisture was furnished, hatching took place and the incubation period was reduced to 15 days. It will thus be seen that a moist atmosphere is essential to the hatching of eggs under a constant high temperature.

In experiments relating to the effects of low temperatures on eggs, by means of a refrigerator a mean temperature of about 45° was maintained, with a minimum of 32° and a maximum of 65°. The eggs were kept in pill boxes with gauze tops to allow free circulation, except during the period of refrigeration, when the ordinary covered pill boxes were used. The eggs from about 20 engorged ticks, collected on July 26, were placed in the refrigerator on August 4 and remained for 30 days. Hatching began on September 23, and about 60 per cent of the eggs were viable.

In the case just referred to, the normal period of incubation was increased, as the result of refrigeration, by 8 days. In a long series of similar experiments, however, in which the period of refrigeration ranged from 1 to 21 days, the period of incubation was not appreciably lengthened and the normal percentage of hatching took place.

In a series of experiments with alternate cold and normal temperatures the eggs were kept in a refrigerator exposed to a mean temperature of about 45° F. from 8.30 p. m. to 8.30 a. m. During the day the eggs were removed from the refrigerator and remained at the temperature of the air. After six consecutive nights of exposure in this way from 5 to 10 per cent of the eggs hatched. It is probable that the necessary manipulation in these experiments interfered with the viability of the eggs and that normally a considerably greater percentage would hatch under the same conditions.

SUBMERGENCE OF EGGS IN WATER.

Sixteen different lots of eggs were used to determine the effect of submergence in water. One-half were submerged for from 10 to 24 days, and most of the eggs hatched. In another lot submerged for 25 days 33 per cent hatched. The experiments were performed from June to September and the incubation period under water was not appreciably different from the normal at the different periods at which submergence took place. In all these experiments complete submergence was secured by means of a screen obstruction below the surface of the water. Our results agree with those recently published by Messrs. Newell and Dougherty and with unpublished data obtained by Prof. H. A. Morgan, who suggested our experiments.

The practical importance of these experiments is to show that the flooding of pastures would have no effect whatever on the viability of tick eggs on the ground. Not only would the great majority hatch, but the time of hatching would not be materially different from that in case no water whatever were present. As a matter of fact the flooding under some conditions, as, for instance, during a drought, might hasten incubation.

These data, taken in connection with data mentioned elsewhere, showing the remarkable resistance of seed ticks to water, indicate clearly the reason why pastures overflowed for considerable periods have repeatedly been found to furnish tick infestation.

A series of eggs varying from those recently deposited to others about to hatch were submerged in tube-form vials. To keep the eggs submerged absorbent cotton was pressed down into the water. None of the eggs hatched, and we suppose this was due to insufficient aeration.

Several lots of eggs that were kept in pill boxes until they had become thoroughly dried were placed on water in Stenter dishes to determine if hatching would follow. After submergence for a short period the eggs in large part filled out and appeared viable, but did not hatch.

PERCENTAGE OF EGGS HATCHING.

To determine the exact percentage of eggs hatching is a rather difficult matter for the reason that manipulation in counting interferes greatly with their viability. In June, July, and August, 1906, a number of observations were made showing the percentage of viable eggs in different lots from 30 to 90. In these cases the eggs were counted, and it is likely that the percentage hatching under natural conditions is considerably higher than that indicated. The examination of masses of eggshells where hatching has taken place normally reveals few unhatched eggs.

Messrs. Newell and Dougherty[a] have recorded a percentage of hatching during the months of April, May, June, July, August, and September of from 61.6 to 92. These experiments were performed at Baton Rouge, La., under conditions which approached the natural ones very closely, although the eggs were counted as in our experiments.

LARVAL OR SEED-TICK STAGE.

The larval tick is a minute 6-legged creature without distinct genital opening, and with indistinct stigmata between the second and third pairs of coxæ. As Salmon and Stiles state, larval ticks frequently show indications, at least, of stigmata between the first and second pairs of coxæ, and behind the posterior coxæ in addition to those between the second and third pairs. Only the pair first mentioned seem to be functional. The color of the larva at first is whitish but soon becomes dark brownish.

NONPARASITIC PERIOD.

For a few hours the larva remains about the shell from which it has just emerged, but later makes its way upward on the first blade of grass, stick, post, or other support that presents itself. Professor Morgan informs us that he has seen seed ticks on the tips of sugar cane about 8 feet from the ground. By placing a pole in the vicinity of millions of seed ticks we have observed them to reach a height of about 6 feet in a surprisingly short time; but the tendency is strongly to remain not more than about 4 feet from the ground. In the absence of some vertical object the seed ticks do not seem to scatter to any great extent, but collect on the highest immediate point, even if it is only a small clod or stone.

On whatever support the young ticks happen to be, they collect in masses often nearly an inch in diameter. (See Pl. I, fig. 2.) Here they remain for weeks or months awaiting a host. The front legs, which combine the functions of antennæ and legs in the insects

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[a] La. Crop Pest Comm., circ. 10, p. 24.

proper, are waved through the air more or less constantly, and violently when a moving object approaches. The ticks attach themselves to any animate or inanimate object which touches them. Only those that happen to attach themselves to cattle (and rarely a few other animals) ever develop; the others either die or, dropping off, become widely scattered.

Heavy rains wash the seed ticks to the ground, and it is possible that violent winds may also serve to disseminate them. In our experiments they have thus been spread to a distance of 5 or 6 feet.

It is noticeable that the seed ticks shun direct sunlight. We have repeatedly seen bunches move halfway around the support with the shade. In the morning they would be on the west and at night on the east side.

EFFECT OF WATER ON SEED TICKS.

Interesting data having a bearing on the dissemination of the cattle tick through the agency of water courses have been obtained. It has been noted that heavy rains wash seed ticks from their supports to the ground. In a considerable number of experiments seed ticks were found to endure submergence varying in different lots from 10 days to 157 days. The latter record was obtained in an experiment in which seed ticks were first placed in water in a Petri dish and a few days later removed to a tube with earth on the bottom. The details of these experiments are given in Table IV.

It is doubtless true that dissemination by water courses is not quite as important as these results would indicate. Of course it is possible that seed ticks may be carried many miles and deposited on grass or bushes, from which they may reach cattle. The enormous scattering of ticks so submerged in water, as would be the case in floods, would undoubtedly greatly reduce the chances of infestation in pastures.

TABLE IV.—*Effect of water on seed ticks.*

Eggs hatched.	Seed ticks submerged.	Longevity, submerged.	Remarks.
		Days.	
Sept. 2	Sept. 4	47	Eight inches of water in tub.
	Sept. 30	157	In Petri dish; Oct. 9 removed to tube with dirt on bottom.
Oct. 4-11	Nov. 11	14	Alive on Nov. 25, and may have lived longer.
Sept. 1	Sept. 1	12	In tub with sand and vegetable matter.
	Aug. 4	41	In Petri dish on porch, with algæ in water.
Aug. 16-17	Aug. 17	32	In Petri dish on laboratory desk.
Aug. 21-25	Aug. 21	17	Submerged as eggs.
Aug. 4-11	Sept. 4	10-17	Submerged as eggs. Culicid larva may have interfered.

Some years ago Professor Morgan obtained interesting results on the effect of low temperature on seed ticks. In brief, he found a temperature of 15° or 16° F. for a short period did not kill many seed

ticks, but that such a temperature continued for 24 hours resulted in the death of practically all. Our experiments have been of two classes—(1) in water and (2) without water. In both cases the seed ticks were subjected to a temperature somewhat less than 32° F. In the case where water was supplied solid ice was obtained. Both in and out of water the seed ticks survived a freezing temperature of one hour's duration, although there was perceptible mortality among them.

LONGEVITY OF SEED TICKS.

The time that seed ticks may survive without a host is a most important matter in plans for control. Our experiments on this point have been of two kinds—(1) with seed ticks from eggs deposited by females placed on the ground in favorable circumstances, thus giving absolutely natural conditions, and (2) with seed ticks in glass tubes, where they could be observed more closely.

In the first series, which was instituted at the suggestion of Professor Morgan, several hundred engorged ticks were placed on the ground at regular intervals. The only inclosure was a cylinder of 2-inch-mesh wire screen about 4 feet in diameter to prevent disturbance. The seed ticks from females placed under these conditions accumulated in enormous numbers on the blades of grass or stakes provided for the purpose (see Pl. I, fig. 2). Table V gives the number of days the seed ticks survived in these experiments, together with other data. It will be seen that the shortest period was 49 days and the longest 159+ days. However, the important period is from the time of dropping of the adults to the death of the resulting seed ticks, since the farmer must always suppose in rotating his cattle that adults were dropped on the day of removal from the pasture which it is desired to clean. This period ranged from 91 to 175+ days. It will be noted that there is considerable variation in the period of survival, even at the same season of the year. This seems to depend upon two factors, namely, the number of seed ticks in the bunches and the amount of rainfall. The larger masses survive longer, perhaps because the moisture is better retained, and heavy rains scatter and reduce the masses. It is probable, on account of the very large numbers of seed ticks in our experiments, that the periods given in the tables are somewhat longer than normally occur in the field. However, such excessive numbers do sometimes occur in nature. For instance, when an animal dies of gross infestation thousands of ticks deposit in a very restricted area. Mr. J. D. Mitchell has seen cases of this kind in which the bunches of seed ticks were fully as numerous as in our experiments.

TABLE V.—*Longevity of seed ticks of Margaropus annulatus Say, at Dallas, Tex., 1906.*

When dropped.	Period from dropping to completion of oviposition.		When hatched.	Seed ticks all dead.	Maximum period from dropping to death of all seed ticks.	Period of life of seed ticks.
	Minimum.	Maximum.				
	Days.	*Days.*			*Days.*	*Days.*
June 20	12	18	Aug. 12	Oct. 8	110	57
June 23	12	18	Aug. 15	Oct. 21	120	[a] 67
May 19	14	21	July 5	Oct. 20	154	107
July 21	12	19	Aug. 14	Oct. 15	86	62
Do	8	16	Sept. 1	Oct. 20	91	49
Aug. 6	8	16	Sept. 14	([b])	175+	159+

[a] In this experiment the seed ticks were accidentally disturbed. They would have lived some days beyond the period indicated.
[b] Some alive Feb. 20, 1907.

In the second series of experiments to determine the longevity of seed ticks the eggs were placed in glass tubes with open bottoms. As will be seen from the footnotes to Table VI certain seed ticks in tubes were shaded at all times, others in tubes were exposed constantly to the sun, while the remainder were placed in pill boxes protected from sun and rain. It is supposed that these diverse conditions give an average length of survival that approaches closely to that occurring under natural conditions. The detailed results follow:

TABLE VI.—*Longevity of seed ticks of Margaropus annulatus Say, Dallas, Tex., 1906.*

Eggs deposited.	Hatching.[a]	Seed ticks dead.	Period from hatching to death.	Period from deposition to death.	Conditions.
			Days.	*Days.*	
Apr. 13	June 5	Aug. 28	84	138	([b])
Apr. 14	May 30	Aug. 15	77	124	([b])
Apr. 15	May 31	Aug. 22	83	130	([b])
Apr. 27	June 4	Aug. 28	85	124	([b])
May 13	June 14	Sept. 20	98	131	([b])
May 15	June 12	Oct. 5	115	144	([b])
May 28	June 23	do	104	131	([b])
May 30	June 26				([b])
May 31	June 27	Aug. 9	43	71	([b])
June 9	July 5	Sept. 26	83	110	([b])
June 10	do				([b])
June 11	July 7	Sept. 22	77	104	([b])
June 21	July 18	Aug. 15	28	56	([b])
June 22	July 14	Aug. 28	45	68	([c])
June 24	July 16	Aug. 6	21	44	([b])
Do	do	Oct. 6	82	105	([c])
June 30	July 20	Sept. 26	68	89	([c])
July 1	July 22	do	66	88	([b])
July 20	Aug. 10	Oct. 20	71	93	([c])
Do	Aug. 14	Aug. 28 (escaped)			([b])
July 22	do				([d])
July 31	Aug. 22	Feb. 18	180	203	([c])
Do	do				([d])
Do	Aug. 23	Jan. 23	153	177	([b])

[a] For details regarding oviposition of these ticks see Tables I and II.
[b] The seed ticks were in open-bottom test tubes in sand in the open air. They were protected from the direct rays of the sun at all times by a cheese-cloth screen. Up to 11 o'clock a. m. they were also shaded by the house.
[c] In open-bottom test tubes in soil exposed to sun at all times.
[d] In open paper pill boxes outdoors, protected from sun and rain at all times.

Considerable numbers of seed ticks in all lots hatching after August 23, 1906, are still alive (February 20, 1907).

PARASITIC PERIOD.

The data already given regarding the periods of preoviposition, incubation, and survival of seed ticks have an important bearing on the time required to free pastures or other inclosures from ticks *provided the cattle are removed.* The data given under the present heading, on the other hand, show the time required *at different seasons to free cattle of ticks by placing them in inclosures from which the ticks have been eliminated either by systematic starvation or by the use of naturally tick-free areas, as, for instance, fields that have been in cultivation for one crop season.*

In this work we have utilized a grade Durham steer, 17 months old at the beginning of the experiments. (See Pl. II, fig. 1.) By means of kerosene emulsion he was carefully cleaned of the thousands of ticks infesting him when obtained. Thereafter he was thoroughly washed to remove traces of the insecticide and hundreds of seed ticks were applied. Under proper precautions to avoid the steer's accidental infestation, these ticks were allowed to reach maturity. After the ticks of each infestation became adult the steer was thoroughly cleaned and placed in another inclosure, which in each case had been carefully disinfected by means of sprays. This process has now been repeated until ten infestations have been reared covering the period between August, 1905, and March, 1907. The details are given in Table VII. In rotation systems the minimum developmental period is the most important, because the cattle must be removed before the earliest developed ticks have had offspring to reinfest them. Therefore special reference is made in the table to the shortest periods found, although the longest and the average are both given.

The following deductions may be made from this table:

1. The period from attachment to dropping ranges from 21 to 58 days. It should be noted that in the longest periods the limit was reached by only one or two belated ticks, the majority approaching the average.

2. The average period ranges from 26.5 to 43 days.

3. The average parasitic period is normally some days longer in winter than in summer. But warm winter weather, as happened in infestation No. 9, may reduce the period even below the average for the summer.

4. The slowest developing ticks of one infestation may occupy from 10 days (in the summer) to 32 days (in the winter) longer than the most rapidly developing ones. The rapidity of development of the ticks of the same infestation depends somewhat upon their location. Those on the portions of the body where the blood supply is most abundant develop most quickly. In general it seems that heavy infestations develop a little more quickly than light ones. This may be

due to the fact that, in light infestations with widely scattered ticks, fertilization is less likely to take place than in other cases where the males may find the females more readily. We have been unable to determine that unfertilized females occupy longer in development than those that are fertilized, but our impression is that they do.

The table also shows that the principal variation in the time of development of the ticks of the same infestation takes place not in the larval or nymphal but in the adult stage.

TABLE VII.—*Development of Margaropus annulatus on steer at Dallas, Tex.*

Application No.	When applied.	First molt.	Minimum larval stage.	Second molt.	Minimum nymphal stage.	Adults dropped.		Minimum period adult stage.	Number removed or dropped.	Period from attachment to dropping.		
						First.	Last.			Maximum.	Minimum.	Average.
	1905.		*Days.*		*Days.*			*Days.*		*Days.*	*Days.*	*Days.*
1	Aug. 16	Aug. 28	12	Sept. 2	5	Sept. 15	Sept. 27[a]	13	20	42	30	36
2	Sept. 27	Oct. 4	7	Oct. 12	8	Oct. 21	Nov. 8	9	10	42	24	33
3	Nov. 11	Nov. 22	11	Nov. 28	6	Dec. 8	Jan. 9	10	13	59	27	43
	1906.											
4	Jan. 16	Jan. 25	9	Feb. 3	9	Feb. 17	Mar. 8	14	11	51	32	41.5
5	May 22	May 31	9	June 6	6	June 14	June 30	8	9	39	23	31
6	June 29	....	....	July 16	....	July 24	Aug. 5	8	5	37	25	31
7	Aug. 2	Aug. 10–11	8–9	Aug. 18	7–8	Aug. 25	Sept. 11	7	14	40	23	31.5
8	Sept. 5	Sept. 12	7	Sept. 22	10	Sept. 26	Oct. 6	4	236	31	21	26.5
9	Oct. 6	Oct. 14	8	Oct. 21	7	Oct. 30	Nov. 12	9	200	37	24	30.5
10	Nov. 29	Dec. 8	9	Dec. 14	6	Dec. 22	Jan. 1	8	55	33	23	28
	1907.											
11	Jan. 1	Jan. 8	7	Jan. 14	6	Jan. 24	Feb. 3	10	35	33	23	27.5

[a] Removed.

DEVELOPMENT ON HOST.

When the larval ticks find themselves on the host they rapidly disappear in the hair and attach themselves to the skin. They are principally found on such parts as the legs, belly, and dewlap that come in contact with the bunches on the grass, but may be found on any part of the host. In cases of severe infestation they practically cover the entire surface of the body, even the eyelids being infested.

In from 7 to 12 days the larval ticks molt and enter the nymphal stage, in which they have eight instead of six legs. The nymphal stage is further distinguished from the larval stage by the presence of a pair of large stigmata quite in contrast to the rudimentary organs of respiration of the larva.

The second molt (from the nymphal to the adult stage) occurs in from five to ten days after the first. The nymph can be distinguished from the adult, which it resembles very closely, by the absence of any genital opening. The process of both molts is undergone by the females while the hypostome is firmly inserted in the skin of the host. The shed skin splits open along either side and drops off in two scale-like pieces. A portion of skin from the capitulum is also shed at the

same time. In the case of males, while during and after the first molt the tick remains fixed to the host, after the second molt it detaches itself and travels in search of a female. As a rule the males molt two or three days ahead of females and frequently two are found attached to the skin of the host directly beneath nymphal females, awaiting the molting of the latter.

When the adult stage is reached the development is very rapid. In from as few as 4 to 14 days the females become fully engorged and fall to the ground to deposit their eggs. They die when the operation is completed.

Although female ticks are somewhat more easily removed at the time of molting than at other times, repeated careful observations show that they do not actually detach themselves at either molt. However, Mr. B. H. Ransom has shown that, when detached artificially just before or after the second molt, females will reattach if placed upon another animal.[a] Likewise he found that ticks removed just after the first molt would reattach after 24 hours. Specimens detached just before the second molt transformed and lived without host for two weeks. Several experiments have led us to the conclusion that only in the rarest accidental cases can reattachment normally take place. In many cases we have attempted to cause detached ticks to reattach, but in only two cases did we succeed. The following are some of the particulars:

February 23, 1906, eight ticks, ranging in size from nymphs to one-half engorged adults, were placed on the shoulder of a steer. The next day all but one of these ticks had disappeared. One, however, which was about one-half engorged, had fastened to the skin about 6 inches from the point where it was placed. This tick was found detached on March 1 and trying to crawl out from the hairs which had been glued together to hold it in place. At this time it was not fully engorged. It began depositing eggs on March 18, and continued oviposition until April 26, reaching a total of 523 eggs. An attempt was made to cause these eggs to hatch, but without success. It is not likely, however, that the failure to hatch was due to the experience of the tick. It is probable that the state of engorgement may have had something to do with the matter, and, moreover, at the time of the year when the eggs were under observation it is exceedingly difficult to cause them to hatch. After the experiment that has been mentioned repeated attempts were made to obtain other cases of reattachment. Ticks at various stages were placed on

[a] Lahille (Contr. l'Étude Ixodidés Argentine, p. 112) had previously detailed a number of experiments in the reattachment of *Margaropus* (*Boophilus*) *microplus*. It was found that immediately after molting the ticks would more or less frequently reattach after being removed artificially. Nothing, however, was found to indicate that the parasites naturally detach and reattach on the host.

the steer and confined to limited area by means of vaccination shields. In no case under this manipulation did reattachment take place. Recently, however, a tick removed just before the second molt became adult in a pill box and reattached after 25 hours.

ADULT STAGE.

Adult females are the ticks that are generally seen, and their appearance is familiar to most persons. The males (which do not become engorged) are generally overlooked, although they may be easily found attached to the skin of the host directly beneath the females. This gives rise to a rather prevalent popular idea that females carry young with them.

The following descriptions are taken from the work of Salmon and Stiles:[a]

Male.—Body oval, narrowed on front, broadest (1.3 mm.) at stigmal plane, 2.15 to 2.35 mm. long. Scutum reddish brown, covering entire dorsal surface, prolonged in front by two pairs of projections—one pair of more prominent dorso-lateral projections, dorsal of anterior projection of coxæ I, and one pair somewhat less prominent and more median, ventro-median of first pair and nearer the neck. Two cervical furrows shallow, extending more or less distinctly to the posterior border; may be somewhat interrupted in the middle; a median furrow present in posterior half, may be very indistinct; posterior margin of body divided into festoons, which may be only slightly marked. Relatively large circular pores, with extruding short bristly hairs, scattered over entire surface. Eyes small and pale, often problematic, at I intercoxal space. Ventral surface lighter than dorsal, all portions provided with short stout hairs; genital pore, broad, transverse, between coxæ II; anus slightly posterior of stigmal plane; two pairs of anal plates (clypei): one pair elongate, rectangular to triangular, close to anus, in some cases extending cephalad to middle of coxæ IV, and caudad to near or beyond posterior margin, the anus being about at the middle of the length, in other cases extending from height of middle of stigmal area to beyond posterior margin of body; the median border longer than lateral border, the former prolonged into a point posteriorly, the postero-lateral margin may be nearly straight, or somewhat curved, or irregular in outline, thus presenting broad tooth-like projections; lateral and contiguous to each of these shields is found another shield somewhat similar in form, but smaller in size. Median caudal appendage absent. Capitulum 450 to 500μ long, base similar to that of the female, but a little straighter, longer, more salient in front of dorsal shield, into which it penetrates by a sort of rectangular neck, lateral projections not very prominent. Mandibles 600μ long, digit about 90μ; internal apophysis with straight base and broad bifide point; external apophysis bidentate, the terminal subventral tooth may be very small while the proximal tooth is strong and large, or both may be large. Hypostome similar to that of female, four distinct rows of teeth on each half. Palpi about 190μ long, similar to those of female. Legs strong; coxæ large, those on each side contiguous, as broad as long; coxæ I triangular, apex may be prolonged anteriorly beyond the corresponding anterior point of dorsal shield, reaching anterior angle of base of capitulum, or may be very short, base posterior and more or less distinctly bidentate, the teeth short, often slightly pronounced, or quite prominent, the lateral tooth in some cases prolonged into a well-marked spine. Tarsi like those of female.

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[a] "The cattle ticks (Ixodoidea) of the United States:" 17th Ann. Rept. Bur. Animal Industry, U. S. Dept. Agric., pp. 420–424, 1901.

Female.—Body elliptical, as broad in front as in back, usually somewhat constricted in middle, near IV pair of legs; may attain 13 mm. long, 7.5 mm. broad. Color exceedingly variable; live specimens vary from a tawny yellow (younger forms) to an olive green (very old specimens), alcohol specimens from yellow to red or black; the excretory system often shows through the cuticle as tortuous whitish canals. Dorsal shield (scutum) very small, visible as a dark brownish spot in a depression at anterior end of median line; usually about 1.1 mm. long by 0.8 to 0.9 mm. broad, decidedly emarginate anteriorly to receive capitulum; lateral borders nearly straight and parallel in anterior portion, from antero-lateral points to eyes, then convergent from eyes caudad, forming a more or less bluntly rounded posterior angle in median line; cervical grooves divide the anterior half of scutum into three more or less equal longitudinal fields, and diverge posteriorly; surface of scutum provided with short bristles which are more numerous near anterior border and near the eyes than elsewhere. Eyes rather small near anterior third of margin of scutum. On nearly the entire length of dorsal surface of body are two antero-posterior grooves, interrupted or nearly effaced near plane of IV pair of legs, and ending a short distance from the shield and from posterior margins of body; also, an unpaired median groove in posterior half of body; all three vary with the muscular contractions and may more or less completely disappear when body is replete. Ventral surface shows four pairs of more or less distinct marginal constrictions corresponding to the four pairs of legs, the IV constriction being most marked, antero-median region also depressed at insertion of capitulum; vulva small, median, at plane of coxæ I; sexual grooves corresponding to the paired dorsal grooves; but showing some variation in different specimens; median groove extending from anus to posterior margin. Anus about on border of second and last thirds of body. Stigmata short oval; stigmal pore slightly crescentic, convexity lateral; stigmal field with numerous larger and smaller wart-like structures, forming a zone near the margin. Cuticle of entire body finely wrinkled, bearing short hairs. Capitulum very short, about 800μ from posterior dorsal margin to anterior end of hypostome; base of capitulum hexagonal, enlarged on its dorsal surface; inserted in emargination of scutum; lateral projections not very prominent. Mandibles 860μ long, digit 120μ. Internal apophysis conical (Neumann), bidentate (Fuller), with its base near the terminal extremity; external apophysis with three successive teeth, one terminal, subventral, small; the second stronger; third large. Hypostome rather spatulate, broad, a little longer than the palpi, provided on each half with four rows of nine to ten nearly regular denticles, which do not extend to the base. Palpi very short (310μ), subconical, articles at least as broad as long; first article partially hidden under the antero-dorsal border of the base of the capitulum; second article pedunculate, dilated in a salient crest in its middle portion, thus forming a prominence inward (toward median line) and outward, and provided with strong hairs, especially on the inner prominence; third article smaller, subtriangular on its dorsal surface, where it forms a projection in and out; fourth article small, cylindrico-conical, infero-terminal. Legs rather thin, short (pair I, 2 mm.; pair II, 2.5 mm), yellowish brown, first articles darker than the others. Coxæ: pair I subtriangular, posterior border bidentate or biundulate, the division in many cases indistinct. Tarsi I unicalcarate, II to IV bicalcarate. Pulvillum about half as long as claws. Stiff bristle-like hairs on all articles.

EFFECT OF CONTINUOUS COLD AND HEAT ON ENGORGED FEMALES.

Twenty-five ticks were used in the experiments with cold, which were conducted during the month of August, 1906. A mean temperature of about 48° F. was maintained, with extremes ranging

from 34° to 53°. With exposure up to 300 hours practically all ticks recovered and in most cases deposited viable eggs. In cases of more than 300 hours' exposure practically all ticks survived, but none deposited viable eggs, although in many instances oviposition took place.

In a number of experiments with heat a mean temperature of from 98° to 102° was maintained. Up to 103 hours of exposure to this temperature practically all ticks deposited eggs that were viable. With exposure at the same mean temperature of from 144 to 218 hours' duration, eggs were deposited, but were found not to be viable. They were dry and shriveled when deposited.

Some of the females survived heating for the longest period, namely, 218.5 hours. With an exposure of 103.5 hours or more, however, at least one-half succumbed.

EFFECT OF DIRECT SUNLIGHT ON ADULTS.

Eleven unengorged females placed in a box exposed to the direct rays of the sun in September died in three days. Seven unmatured females in direct sunlight from morning until noon seemed dead at noon. They did not survive until the next day, although they were removed from the direct sunlight at 2 o'clock. Similar experiments showed that death resulted in the case of engorged females after a few hours' exposure to the sun. In experiments with eggs, tubes were subjected to direct sunlight for one day. When moistened while kept in these tubes, hatching seems to take place normally, and hatching followed in similar experiments in which the eggs were kept dry.

EFFECT OF SUBMERGENCE IN WATER ON ENGORGED ADULT TICKS.

Adult ticks have remarkable resistance to the effect of submergence, as has been pointed out to be the case with eggs and seed ticks. The immediate effect of submergence is to cause a cessation in the activity of the ticks, while they become somewhat distended apparently from the absorption of water. In August and September, 1905, a considerable number of experiments were conducted in which the adult ticks were submerged in water from the city mains at Dallas, Tex. Judging by the experiments with seed ticks and eggs mentioned elsewhere it is not likely that water impregnated with foreign matter would have changed the results. During the months mentioned a period of submergence of 24 hours did not result in the death of any appreciable number of ticks used in repeated experiments. After one or two hours the specimens recovered from the immediate effect of submergence and proceeded to deposit eggs which were found to be

viable. With between 24 and 48 hours' submergence the number of ticks that recovered diminished rapidly. Occasionally specimens recovered after a period of submergence of over 48 hours. For instance, the specimen collected on July 12 and submerged for 50 hours survived and deposited viable eggs. Later in the season (that is, in October) somewhat different results were obtained in experiments in the submergence of adults. In this month many ticks recovered after from 50 to 90 hours of submergence. In fact, fully 50 per cent of the ticks submerged between these extremes regained their full activity. In one experiment two out of five ticks submerged in October for 91¼ hours recovered and deposited viable eggs. Nevertheless a number of ticks submerged for 115¼ hours did not recover.

The results that have been mentioned above indicate that where engorged ticks fall from cattle that are standing in permanent pools of water none will survive to deposit eggs. At the same time the results show that temporary flooding of from 24 to 100 hours' duration would not in all cases prevent ticks from depositing eggs. It must be noted in this connection, however, that the vitality of eggs deposited by ticks just prior to temporary flooding would not be interfered with by the water, although, of course, they might be washed away.

DROPPING FROM HOST.

It is a more or less prevalent popular idea that ticks have some sense which enables them to drop from a host in places favorable for oviposition. A few observations have shown, as was supposed in the beginning would be the case, that there is probably no such power of perception present in the cattle tick. The popular impression probably had its origin in the fact that bunches of seed ticks are found most numerously in the places where the cattle collect for the benefit of shade or water. This phenomenon obviously is due merely to the collecting and standing of the cattle.

Many observations seem to show clearly that there is no preference as to the time of dropping. In our experiments many ticks have been known to drop from host during the night and many others to drop during the day.

LOCOMOTION.

Some attention has been paid to obtaining data on the distance engorged ticks may travel after dropping from the host, since this has a practical bearing on double fencing in eradication work. In some experiments specimens were placed on the floor in the laboratory and allowed to move at will. The total movement varied from 24 inches to 123 inches, the latter distance being covered in 52 minutes.

The effect of antiheliotropism was always in evidence in these experiments. The light was admitted from different quarters at different times and the ticks always changed their course so as to travel away from it. These results are very similar to those published by Lahille from experiments with *Margaropus (Boophilus) microplus* in Argentina. The distance engorged females will travel depends upon how soon they can reach shelter. If they obtain protection under débris of any kind they seem to be disinclined to go farther. The greatest distance traveled on the ground out of doors was only 24 inches.

It is popularly supposed that engorged female ticks often burrow into the ground. In a number of experiments with light barnyard trash in tubes it was found that females will work their way down from one-half to 1¾ inches. In such cases the masses of eggs assume various shapes on account of the surrounding débris. (See Pl. I, fig. 1.) It was found that seed ticks from eggs so deposited had no difficulty in reaching the surface.

HOST RELATIONS OF THE CATTLE TICK.

Margaropus annulatus was described in 1829 by Say "from specimens taken on a Virginia deer in Florida." Since that time we have been unable to find records of the occurrence of the species on deer. However, a number of instances have come to light recently in which undoubted specimens of *Margaropus annulatus* have been found on deer. The first of these cases was the result of an examination made by Mr. R. C. Howell on a herd of tame deer in a park at Mount Pleasant, Tex., in October, 1905. Since that time Mr. J. D. Mitchell has found specimens on a deer at Oakville, Tex. Mr. T. R. Coker has sent specimens from the same locality and host. In both of these instances the ticks were found on wild deer that had just been shot. In February of the present year Mr. F. C. Pratt collected a few specimens of *Margaropus annulatus* from a dry deer hide at Kerrville, Tex., and in December he examined a fresh hide on which considerable numbers were found.

The matter of the possible development of *Margaropus annulatus* on various animals, among them guinea pigs, rabbits, dogs, and cats, has been studied by various investigators. Dr. J. W. Connaway's experiments in Missouri in 1897 showed that the ticks would not attach to rabbits or guinea pigs. They did attach to dogs in considerable numbers, but only one of them ever matured. Recently Mr. B. H. Ransom has repeated the experiments with rabbits, dogs, and cats. On rabbits and dogs the ticks attached, but remained so only a short time. On a cat a female tick remained attached from July 25 to August 30 and molted on the host. Nevertheless, it did not reach engorgement.

In our experiments with ticks we have kept several dogs primarily for experiments with species other than *Margaropus annulatus*. At the same time we have repeatedly sprinkled thousands of seed ticks of *Margaropus annulatus* on these dogs, but in no case have we noticed that attachment took place. This, with the work of Connaway, Schroeder, and Ransom, seems to indicate that dogs can play but a very unimportant part as hosts for the cattle tick. Ransom mentions the fact that the collection of the Bureau of Animal Industry contains specimens of *Margaropus annulatus* collected from a dog, from which host Francis (1894) seems to have been the first to report it.

One of the writers has had one case of an attachment of *Margaropus annulatus* to his person. This was a male specimen that attached between the fingers of the hand. It was removed after about half an hour. Mr. Ransom mentions a similar case in which, however, the specimen was a female and remained attached to his hand for twenty-four hours before it was removed. Attachment to human beings must be very rare. The junior author had worked with thousands of specimens of ticks before and after the single case of attachment that has been mentioned.

In addition to the abnormal and unusual host relations mentioned above, there are not infrequent instances in which *Margaropus annulatus* has been found to occur on horses, mules, and asses.

All this work shows clearly the remarkable host restriction of the cattle tick that is most important from the viewpoint of its attempted eradication.

The early records of Packard, showing the occurrence of the cattle tick on a porcupine and a similar record of its occurrence on the rabbit in Idaho, must have been due to a misidentification of the species.

The strict instinct for the proper host in the cattle tick is shown in the extreme infrequency of attachments of ticks to each other. Thousands of ticks have been sent to the laboratory alive inclosed together in tin or wooden boxes. In only one case was it found that a tick had inserted its rostrum in another. This happened in a lot collected in southwest Texas by Mr. J. D. Mitchell on April 19. A female had inserted its beak firmly on the lateral dorsal portion behind the posterior coxæ. The two specimens were placed in alcohol and still remained connected.[a]

RELATION BETWEEN RATION AND TICK INFESTATION.

For several months after experiments were started at Dallas in placing seed ticks on the steer used for experimental purposes it was found that a surprisingly small proportion ever became adult. In

[a] Since the above was written important discoveries regarding the occurrence of *Margaropus annulatus* on sheep have been made by the Bureau of Entomology. See Circular 91, Bureau of Entomology, U. S. Department of Agriculture, issued July 3, 1907.

many cases from 5,000 to 10,000 seed ticks were placed on the animal, but only from 1 to 20 adults ever developed. Prof. H. A. Morgan made the suggestion, based upon the observations made by him in Louisiana, that the ration the steer was receiving was responsible for this remarkably small proportion developing. At his suggestion we changed the ration. The steer had been receiving daily 4.76 pounds of corn chops and 5 pounds of prairie hay. The inspection tag on the chops guaranteed not less than 9 per cent protein crude and not less than 4 per cent fat crude. At Professor Morgan's suggestion the corn chops were eliminated. Immediately a much larger percentage of seed ticks developed to adults on the animal, although his general condition did not seem to have been changed materially. While before a dozen adults from many thousand seed ticks was the maximum, after the change in the ration hundreds developed from no larger numbers of seed ticks applied.

ENEMIES OF TICKS.

At one time it was supposed that sowbugs may sometimes be important factors in the destruction of tick eggs. A number of observations have shown that the greatly preferred food of these isopods is vegetation either live or decayed. In laboratory experiments *Armadillidium vulgare* was found to feed on dead ticks and also to devour the eggs whenever no other food was provided. Thirty-eight sowbugs, furnished with 897 tick eggs, consumed 366 at the rate of 3 eggs per day each. In another case two sowbugs devoured 159 tick eggs at the rate of 15 each per day. These results hardly seem to substantiate the impression that sowbugs may be of considerable economic importance. It should be emphasized that the experiments referred to were conducted in the laboratory, and the sowbugs were deprived of other food. Under natural conditions the results might have been quite different.

The little "fire-ant" (*Solenopsis geminata* Fab.), which has recently been found to be acquiring a special taste for the boll weevil, undoubtedly destroys many engorged ticks that have dropped to the ground. Experiments performed by placing ticks in the immediate vicinity of nests of this ant show that under such circumstances they must invariably be killed. The nests of this ant are found throughout the pastures in the South, and the total of the work done by them must be considerable.

A number of dipterous larvæ have been found feeding upon tick eggs and an undetermined species of Phoridæ has been bred.

At one time we were inclined to believe that a chalcidoid parasite of the cattle tick had been reared. Early in 1906 such a parasite was found in a pill box with the remains of an engorged tick placed there the fall before. Upon sending the specimen to Dr. L. O. How-

ard it was learned that it belongs to a new species and genus. Chalcidoids of the subfamily to which it undoubtedly belongs are known to be parasitic on various dipterous larvæ. Upon reexamination of the remains of the tick a portion of a dipterous cocoon was found. Consequently the hymenopteron was probably not a parasite of the tick, although the interest remains, since the dipteron was probably parasitic on the tick.

A number of observations have been made showing that domestic fowls frequently learn to remove ticks from cattle in barn lots. Mr. F. C. Pratt observed a case in which the fowls regularly visited hides hanging up to dry for the purpose of picking up the ticks which dropped from them. Mr. J. D. Mitchell has witnessed "jackdaws" (*Quiscalus major macrourus*) picking ticks from cattle near Victoria, Tex., and the farmer informed him that he believed these birds kept the cattle practically free of engorged or nearly engorged specimens. Mr. S. E. McClendon, of the Louisiana Experiment Station, informs us that he has repeatedly seen kingbirds (*Tyrannus tyrannus*) engaged in the same work.

In connection with the enemies of ticks it may be stated that it seems likely that mice are of some importance. In the laboratory it was found that the best bait for mouse traps that could be used was engorged cattle ticks. It seems likely that in the pastures field mice may frequently devour ticks. Dutton and Todd (Human Tick fever, p. 17) write as follows: "Ticks are not without natural enemies. Rats eat adults with avidity, and ants carry off young ones and eggs. We have lost ticks in both ways. One occasion over two hundred young ticks were carried off in a single night by small ants." These remarks apply to *Ornithodoros moubata* in West Africa.

THE PRACTICAL APPLICATION OF THE INFORMATION RECORDED IN THIS BULLETIN.

In the preceding pages at different places the special practical importance of the data discussed has been mentioned. As a matter of fact the work upon which this bulletin is based has been planned to accumulate additional information for use in the practical work of tick eradication. Some methods of control are satisfactory in certain districts, but much less so in others. Plans that would be feasible along the northern border, for instance, where the tick is on a rather delicate equilibrium and is never found on the cattle for months during the winter, would not be applicable to the moist regions along the Gulf where the cattle are infested throughout the year. Of the various methods of eradication undoubtedly those of the widest utility are the ones which prevent the development of the ticks by breaking up the relation between them and the cattle. Of these, the more important are the feed-lot or soiling system for relieving the

cattle of ticks and the pasture-rotation system (to be used in conjunction with the former) for freeing the pastures.

In the feed-lot or soiling system the basis is the time occupied for development on the host in connection with the time from the dropping of engorged females to the hatching of seed ticks from eggs deposited by them. In a tick-free inclosure, as a feed lot, cattle may be left to drop their ticks until it is time for the eggs from the first-dropped individuals to hatch. Information as to exactly when it will be necessary to move the cattle to avoid reinfestation is given in Tables I and II, which show the numbers of days at different seasons before ticks begin to oviposit after dropping and the time before the first eggs deposited will hatch. In July, 1906, for instance, this was from 25 to 27 days. The time required for all ticks to drop from cattle, which indicates how long they must remain in one or more tick-free areas, is shown in Table VII. The period is from 31 to 59 days.

The data necessary for an intelligent plan of freeing pastures, by removing the cattle until the death of the ticks, are given in Tables V and VI, showing the period from dropping to the death of all the resulting seed ticks. The former table shows that if cattle were removed from a pasture on June 20, 110 days later it would be perfectly safe to consider it tick-free.

The data referred to above, together with the results of other experiments, have been arranged to cover maximum preoviposition and maximum oviposition periods, for convenience, in Table VIII.

Table VIII.—*Periods in the life history of the cattle tick upon which means of control are based.*

When ticks dropped.	Period from dropping to oviposition.		Minimum incubation period.	Minimum period from dropping of ticks to hatching of eggs.	Seed ticks all dead.	Maximum period from dropping of adult to death of seed ticks.
	Minimum.	Maximum.				
1905.	*Days.*	*Days.*	*Days.*	*Days.*		*Days.*
Sept. 2	3	5	43	46	June 22	293
Do	3	5	56	59	May 31	271
Dec. 23	21	41	54	75	Aug. 28	248
Dec. 24	21	41	47	68	Aug. 15	234
Dec. 25	21	41	47	68	Aug. 22	240
1906.						
Mar. 20	9	10	39	48	Aug. 28	161
Apr. 19	5	6	33	38	Sept. 20	154
Apr. 21	5	6	29	34	Oct. 5	167
May 1	6	10	27	33	...do...	157
May 4	6	10	28	34	Aug. 9	97
May 19	4	6	27	31	Sept. 26	130
May 21	4	6	27	31	Sept. 22	124
June 3	3	5	28	31	Aug. 15	73
June 4	3	5	23	26	Aug. 26	a 83
June 6	3	5	23	26	Aug. 6	a 61
Do	3	5	23	26	Oct. 6	122
June 12	3	4	21	24	Sept. 26	106
June 13	3	4	22	25	...do...	105
July 1	3	5	22	25	Oct. 20	a 111
July 13	3	4	23	26	Feb. 18	a 220
Do	3	4	24	27	Jan. 23	194

a These ticks were kept in open-bottom test tubes exposed to sun at all times.

In the above experiments (Table VIII) the eggs and seed ticks, except those marked ([a]), were kept in cylindrical tubes of $\frac{1}{2}$-inch diameter inserted for about $1\frac{1}{2}$ inches into sand or soil in receptacles on or below the surface. These were kept in a cage on the west side of the laboratory so that they were protected from the sun until 11 a. m. As soon as the eggs commenced to hatch, there was placed in the tube a stopper of absorbent cotton which remained unremoved until the death of the ticks. In cases marked ([a]) the conditions were the same, except that the tubes were exposed to the sun at all times.

The conditions furnished included a humid atmosphere and a minimum temperature as compared with the normal. The enforced bunching and protection from wind and rain furnished additional favorable conditions. It would seem that the periods are maxima and hardly to be met with in the work of extermination. One unfavorable factor met with, which could not be prevented, was the growth of algæ on the inside of some of the tubes. This accounts for some of the variation in the longevity.

In addition to the main practical data given the following are of importance:

All experiments and observations show the close host restriction of the cattle tick. Though the occurrence of the cattle tick on deer, horses, mules, asses, and some other animals is comparatively rare, it must be taken into consideration in the practical work of tick eradication.

Eggs are but little affected by water. When submerged, they hatch in about the normal time. Seed ticks are also resistant to water. In one case seed ticks survived submergence of 157 days. Adults are less resistant, but in the summer they frequently survived submergence of 48 hours. Later in the season the resistance seemed to be greater, some females surviving after more than 90 hours. It is evident that water courses must play a very important part in tick dissemination.

The adult cattle tick has only the most limited means of locomotion. After it drops from the host it crawls but a few feet at the most. On the ground in our experiments the greatest distance traversed was only 24 inches.

On the whole, no very important enemies of ticks have been found. Domestic fowls frequently devour considerable numbers of them, and some wild birds also render valuable assistance in picking them off animals or from the ground.

NOTES ON VARIOUS SPECIES OF TICKS FOUND IN THE UNITED STATES.

The rôle that *Margaropus annulatus* Say was found by Smith and Kilborne to play in the transmission of splenetic or Texas fever in cattle impressed upon investigators the importance of ticks as carriers of disease. Since that time the study of these creatures has progressed rapidly. Smith and Kilborne, Lounsbury, Theiler, Marchaux, Salimbeni, Dutton and Todd, Motas, Kossel, Ricketts, and King are among those who have demonstrated that ticks are the agents through which various diseases of man and other animals are transmitted. What is greatly needed in this country at the present time is a convenient means of identifying the various species. This the writers have attempted, in a measure, to supply in the following pages, in which will also be found notes on the life history and habits of such species as they have encountered.

CLASSIFICATION AND HABITS OF TICKS.

The following key will enable one to determine the genera of the various ticks found in this country:

KEY TO FAMILIES, SUBFAMILIES, AND NORTH AMERICAN GENERA OF TICKS, (IXODOIDEA).[a]

Scutum absent . . . . Family ARGASIDÆ.
Scutum present . . . . Family IXODIDÆ.

Family ARGASIDÆ.

Capitulum at least its length from the anterior margin . . . . Genus *Argas* (p. 42).
Capitulum under a beak-like projection, close to anterior margin.
Genus *Ornithodoros* (p. 45).

Family IXODIDÆ.

1. Palpi short, not or only slightly longer than broad; capitulum short.
Subfamily RHIPICEPHALINÆ, 2
Palpi plainly longer than broad; capitulum longer . . . . Subfamily IXODINÆ, 5

Subfamily RHIPICEPHALINÆ.

2. Dorsal surface of capitulum hexagonal, the sides projecting in angles; male with anal plates 3

[a] This table is based upon those of Salmon and Stiles (1901) and Banks (1904). The genus Ceratixodes is not included (see p. 54).

Dorsal surface of capitulum rectangular, sides straight; male without anal plates..4

3. Second and third palpal segments extend laterally into sharp points; stigmata nearly circular..........Genus *Margaropus* (p. 49).

Second and third palpal segments even; stigmata comma-shaped. Genus *Rhipicephalus* (p. 47).

4. Eyes present; external border of palpi straight; coxæ I bidentate. Genus *Dermacentor* (p. 49).

Eyes absent; external border of palpi uneven; coxæ I not bidentate. Genus *Hæmaphysalis* (p. 52).

Subfamily IXODINÆ.

5. Anal groove surrounds anus anteriorly and opens posteriorly; eyes absent; stigmal plate nearly circular..........Genus *Ixodes* (p. 54).

Anal groove surrounds anus posteriorly and opens anteriorly; eyes present; stigmal plate reniform..........Genus *Amblyomma* (p. 58).

Lahille has recently[a] published an ingenious graphic table for the separation of the families and genera of Ixodoidea. It is reproduced

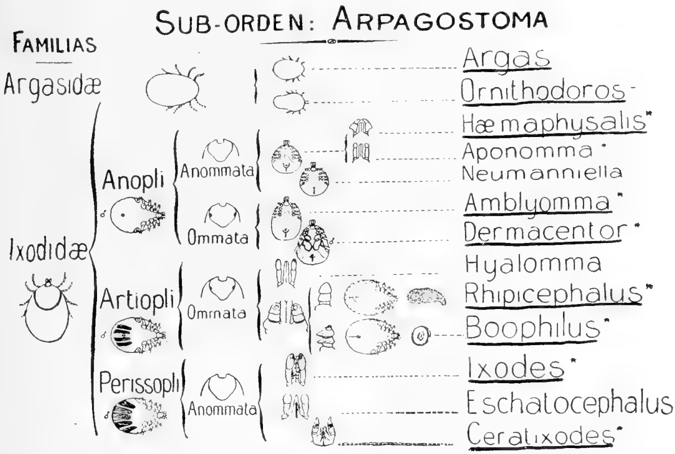


FIG. 2.—Graphic table for the separation of the families and genera of ticks. (From Lahille.) The underscored genera are represented in the United States.

here as figure 2. The genera underscored are known to be represented in the United States. The suborder Arpagostoma of Lahille is the same as the superfamily Ixodoidea of Banks, used by us.

Family ARGASIDÆ.

The family Argasidæ is represented by two genera, Argas and Ornithodoros. They are readily distinguished by the characters given in the table. The species are parasitic on mammals and birds.

[a] Ixodides Argent., 1905, p. 21.

Genus ARGAS.

The species belonging to the genus Argas are nocturnal parasites of chickens, pigeons, and other birds, and occasionally attack mammals, man included. Two species are represented in this country—*A. miniatus* Koch and *A. sanchezi* Dugès. The former has been found by Marchaux and Salimbeni to transmit spirillosis of fowls in Brazil. There is some evidence of the occurrence of this disease in the United States.

ADOBE TICK.

(*Argas sanchezi* Dugès.)

This species was described in 1891 by Dugès from larvæ collected at Guanajuato, Mexico, on a dove (*Zenaidura macroura*). In structure it is very similar to *A. miniatus*. Neumann's description is based upon a number of specimens collected at Mariposa, Cal., upon a quail, and at Santa Agueda, Lower California, upon a wild turtle dove. Mr. Nathan Banks has specimens from Deming, N. Mex., and from Arizona, and it is quite probable that it will be found in Texas, and possibly farther north. Mr. Banks states that in New Mexico it is found in houses and is there known by the common name used above.

FOWL TICK.

(*Argas miniatus* Koch.)[a]

This species was described in 1844 by Koch from Demerara. The name *Argas americanus*, applied by Packard in 1873 and used largely by writers in this country, is a synonym of *A. miniatus*. For excellent illustrations of this species see Salmon and Stiles, Ixodoidea of the United States, Plate LXXII and text figures.

The species is well distributed over the world. The records include Persia, Algeria, Russia, India, Australia, South Africa, Central and South America, and, in the United States, Florida, Texas, New Mexico, Arizona, and California. In southwestern Texas it is found in large numbers in and about chicken houses and out-door roosts, hiding away in crevices by day and coming out at night to engorge on the fowls. This species seems occasionally to attack mammals, as Mr. J. D. Mitchell has taken it once in Texas from the rabbit.

As pointed out by Lounsbury, the sexes are so much alike that, except by the size, the only safe way of separating them is through the form of the genital orifice. To quote from him, "This orifice [genital] is situated just behind the mouth parts on the under side of the front of the body; that of the male is relatively inconspicuous

[a] The name of this tick is in great confusion. The one used by the writers is that recently adopted by Banks.

and is surrounded by an oval ring, and that of the female appears as a transverse slit in the leathery surface. Both sexes are of the same dimensions when they become adult. The male, however, does not perceptibly increase in length and width by feeding, whilst the female does, and hence amongst specimens collected about a fowl house the females are generally larger than the males."

Its life history has been worked out by Lounsbury at Cape Town. As brought out by him, the life cycle and habits are strikingly dissimilar in some important respects from those of the true ticks, the general habits being found much more like those of the bedbug (*Cimex lectularius* L.) As might be expected, we have found the stages in the life cycle to vary somewhat from those he found. Unlike the ticks of the family Ixodidæ, this species feeds for but a few hours at a time, and then always at night, excepting in the larval stage, when we have found it to remain attached for five to eight days before dropping. There is also an extra nymphal molt. Unlike the ixodid ticks again, these do not die following engorgement, but live on, ovipositing repeatedly. Within a week or ten days from one feeding in warm weather they again find a fowl and engorge. As many as five different feedings as adults have been recorded by Lounsbury, each followed by the deposition of eggs.

In our experiments seed ticks were placed upon a fowl and observations made to determine the period of larval attachment. In about three days from attachment they became rounded and black from the engorgement of blood. A few hours before dropping they commenced to flatten and assume the typical Argas shape. Attachment continues for from five to eight days. In September and October fourteen days were found to pass after dropping before molting took place. The attachment for second and third engorgements Lounsbury found to last but a few hours, about two weeks to pass after the second, and a like period following the third engorgement before molting.

TABLE IX.—*Oviposition of Argas miniatus at Dallas, Tex.*

When collected.	First engorgement recorded.	First oviposition.			Number of eggs.
		From—	To—	Number of days.	
1906.					
May 12	When collected	June 23	July 4	12	113
Do	do	May 17	May 30	14	274
Do	do	May 16	May 23	8	158
Do	do	May 17	May 29	13	169
Do	do	May 18	June 3	17	194
Do	do	May 18	May 24	7	50
Do	do	May 16	May 22	7	32
Mar. 24	Apr. 17-18	May 2	May 20	19	130
Do	do	Aug. 1	Aug. 10	10	83

Table IX.—*Oviposition of Argas miniatus at Dallas, Tex.*—Continued.

When collected.	Second engorgement.	Second oviposition. From—	To—	Number of days.	Number of eggs.	Third engorgement.	Total number of eggs.
1906.							
May 12				0			113
Do	Aug. 8–9	Aug. 14	Aug. 24	11	180	Oct. 22–23	454
Do	Aug. 9–10	Aug. 15	Aug. 21	7	199	Sept. 3[a]	357
Do	Aug. 10–11	Aug. 16	Aug. 25	10	193		362
Do	Aug. 15–16	Aug. 21	Sept. 4	15	148	Oct. 17–18	342
Do	Aug. 17–18	0	0	0	0		50
Do	Aug. 23–24[b]						32
Mar. 24	Aug. 7–8	Aug. 17	Aug. 24	8	55	Sept. 28–29	185
Do	Aug. 18–19	Aug. 24	Sept. 2	10	154	Oct. 16–17	237

[a] Dead. [b] Last engorgement.

Adult ticks weighed before and after engorgement were found to increase in weight more than 300 per cent.

In order to determine the incubation period, 35 daily lots of eggs, deposited between May 16 and September 1, were recorded. Of these, four lots commenced hatching in 14 days, 26 in 15 days, and 5 in 16 days. In the incubator eggs deposited August 21 and subjected to a mean temperature of 99.8° hatched on August 29, the maximum temperature being 108°. From experiments carried out by placing eggs and seed ticks in an ice box and exposing them continuously, these were found to be exceedingly resistant to cold. Eggs deposited August 27 were exposed from September 8 to October 1 to a mean temperature of 48.9°, a maximum of 67° and a minimum of 37°. These commenced hatching October 6. Two lots of larvæ, one of 13, that hatched September 2, and a second of 30, that hatched September 8, were exposed in the ice box from September 8 to October 22 to a mean temperature of 45.9°, the maximum being 67° and the minimum 36°. These were all alive when removed and were as active as ever October 25.

At Dallas larvæ kept submerged in water to a depth of about an inch lived for 11 days.

The length of life of this tick and its capacity to exist in the absence of a host are surprising. At Dallas larvæ kept confined in summer in pill boxes immediately after hatching lived about two months, some surviving somewhat longer. Larvæ of *Margaropus annulatus* kept under similar conditions live for but *two or three days* at the most. In Australia Robertson found the nymphs to live in pill boxes for about the same period as we have found the larvæ to survive.

The longevity of the adult, however, is most remarkable. Riley reports an adult specimen as remaining alive in a corked vial without food for five years.[a] Robertson has found them to remain alive for two years and three months and Dr. Cooper Curtice informs us that he has kept them alive without food for more than two years. In our experiments adults collected in March, 1906, and kept in corked

[a] Proc. Ent. Soc. Wash., III, p. 121.

vials are still alive, March 1, 1907, although a number have succumbed. Not less surprising than the longevity of the adult is its resistance to insecticides. Lounsbury has kept adults confined for three months in a box nearly filled with flowers of sulphur with no apparent effect on them. He has also exposed them for two hours to hydrocyanic-acid gas at the strength of 1 ounce of potassium cyanid to 150 cubic feet of space and found that this scarcely served to decrease their activity. Further, many individuals survived for some days after treatment with paraffin and various oils.

Genus ORNITHODOROS.

Ornithodoros, the second genus belonging to the Argasidæ, is represented in the United States by two species, *O. megnini* Dug., and *O. turicata* Dug., both known to attack man.

A species widely distributed through Central and South Africa, *O. moubata*, was reported by Dr. Cuthbert Christy (1903), of the Liverpool School of Tropical Medicine, as the probable transmitter of tick-fever in man. In 1905 Dutton and Todd,[a] not knowing of the work of the other investigators, demonstrated that "tick-fever" in the oriental province of Kongo Free State is a relapsing fever produced by a spirillum, probably *Spirillum* (*Spirachæte*) *obermeieri*, and that this organism can be transmitted by the bite of the tick.

The life cycle of members of this genus has yet to be followed. Lounsbury states that *O. savignyi* begins to engorge at once when applied to a host, and that generally it is off again in an hour. After an engorgement, he states, it rests for many weeks or months and, generally, at least, sloughs its skin if immature or lays eggs if a mature female before again seeking an animal.

It is suspected by Mr. Nathan Banks that a species of the genus transmits a disease of cattle in California.

SPINOSE EAR TICK.

(*Ornithodoros megnini* Dugès.)

This tick was first described in 1883 by Dugès, from Guanajuato, Mexico, as a species of Argas. It has been reported in the United States from New Mexico, California, Kansas, and Nebraska, and is an important tick in Texas. The writers are informed by a rancher in the western part of the State that considerable injury is due to the irritation produced by it in the ears of cattle and that its presence can often be told by the rough appearance of the hair. A prominent stockman in Dewitt County states that, in his opinion, it is second to the fever tick in importance. In addition to cattle it is found upon horses, asses, dogs, and sheep, and has been reported several times from man. Mr. J. D. Mitchell, of the Bureau of Entomology, reports two cases at Victoria, Tex., in which specimens were taken from human ears by a physician, following prolonged severe pain. Mr.

[a] Memoir XVII of the Liverpool School of Tropical Medicine.

Mitchell informs the writers that he has known this tick to climb 3 feet from the ground and deposit its eggs in a crevice on the corner of a house and in other cases in cracks in the bark of trees at about the same height. From the action of specimens confined in nearly vertical vials he supposes that the species normally climbs some distance upward for the purpose of depositing the eggs.

The nymph and adult are quite different in appearance, so much so that Neumann states that he would hesitate to consider the two forms as belonging to the same species had he not found a cast skin about a female. Marx figured the nymph as a new genus and species, *Rhynchoprium spinosum*.

Stiles and Hassall have described and figured a pupa-like stage of this tick. This, however, does not seem to be a true resting stage, as specimens run very actively when removed and placed in boxes. The present writers, from live material in hand, are inclined to consider the so-called pupa-like stage as merely the engorged larva.

The longevity of *O. megnini* seems to be much like that of Argas. A specimen collected by the writers in July, 1905, lived to beyond January 12, 1907, having been kept in a pill box for a year and a half.

TURICATA TICK.

(*Ornithodoros turicata* Dugès.)

This tick was originally described from Mexico. It attacks man, the punctures causing large swellings that remain for several days and are followed by severe pain. It has been reported from South America on the llama; from the United States, in Florida, on a land turtle (*Gopherus polyphemus*) and in a snake's burrow, in Texas on hogs, and in California. We have a specimen taken at Burnet, Tex.

In the Canadian Entomologist for 1900, page 20, Lounsbury mentions the possibility of the African species *O. savignyi* being introduced and identical with *O. turicata*. He states, "Neumann in his monograph does not give extensive ground for separating *O. savignyi* and *O. turicata*. In this country [South Africa], natives are known to carry the tick unintentionally with their belongings from place to place. It might easily have been introduced into America with slaves in the last century or earlier, just as negroes returning to Africa are said to have introduced here the jigger flea (*Sarcopsylla penetrans* L.). This latter insect continues to spread and is now found as far south as Durban, Natal."

Family **IXODIDÆ**.

The members of the family Ixodidæ from their structure naturally fall into two subfamilies as suggested by Salmon and Stiles. The *first*, Rhipicephalinæ, comprises the forms with short, more or less conical palpi, represented in this country by the genera Rhipicephalus, Margaropus, Hæmaphysalis, and Dermacentor; the *second*, subfamily Ixodinæ, includes forms with long palpi and is represented in the United States by the genera Ixodes, Amblyomma, and Ceratixodes.

Subfamily RHIPICEPHALINÆ.

Genus RHIPICEPHALUS.

The genera Rhipicephalus and Margaropus (formerly Boophilus) are structurally so similar that Neumann and Fuller consider our *M. annulatus* as belonging to the genus Rhipicephalus. All species of Rhipicephalus, so far as studied, including five South African forms investigated by Lounsbury and one taken by us, drop from the host for the purpose of undergoing at least one of the molts. The three species placed under Margaropus that have been studied pass both molts upon the host. This would seem to supplement the structural differences in indicating the generic validity of Margaropus.

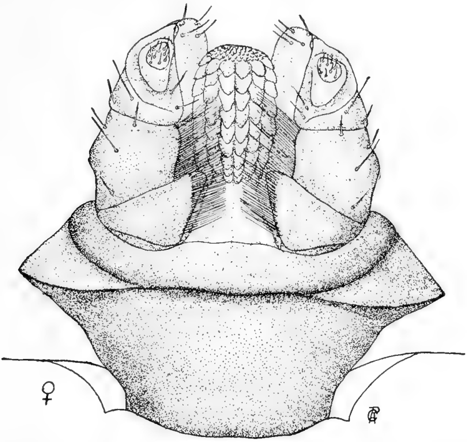


FIG. 3.—*Rhipicephalus* sp.: Capitulum of female, ventral view. Greatly enlarged (original).

BROWN DOG TICK.

(*Rhipicephalus* sp.)

Salmon and Stiles in 1901 stated that they were not acquainted with any North American species, although they called attention to the fact that *R. sanguineus* had been reported by Neumann from Panama, *R. bursa americanus* from Jamaica, and an undetermined species from Porto Rico. Banks [a] records an undetermined species from Colorado. What appears to be a new species has been taken quite generally from dogs in the southern part of Texas and also at Tlahualilo, Durango, Mexico (see figs. 3 and 4 and Pl. III, fig. 5).

[a] The Arachnida of Colorado. Ann. N. Y. Acad. Sci., Vol. VIII, 1905.

It may be called the brown dog tick. Our specimens are from nine different localities and were all taken on dogs. Unlike *Dermacentor variabilis,* Mr. Mitchell informs us, this species occurs on all parts of the body of dogs. Nathan Banks informs us that this form is closely allied to *R. sanguineus.* It is probably the same as was referred to as *R. sanguineus* in the annual report of the Bureau of Animal Industry for 1905, page 35.

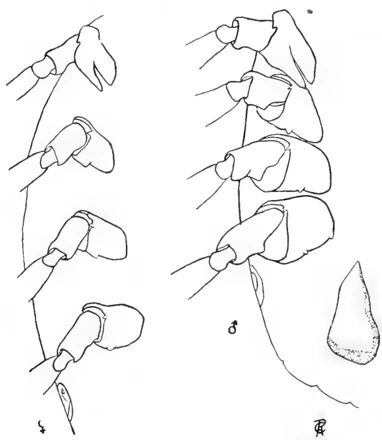


FIG. 4.—*Rhipicephalus* sp.: Coxæ of male and female. Greatly enlarged (original).

Lounsbury has found five species belonging to the genus Rhipicephalus that transmit African coast fever in cattle. The possibility of the transmission of disease by the species we have found remains to be investigated. The following are notes we have made on the life history of this form:

TABLE X.—*Oviposition of Rhipicephalus sp., from dog.*

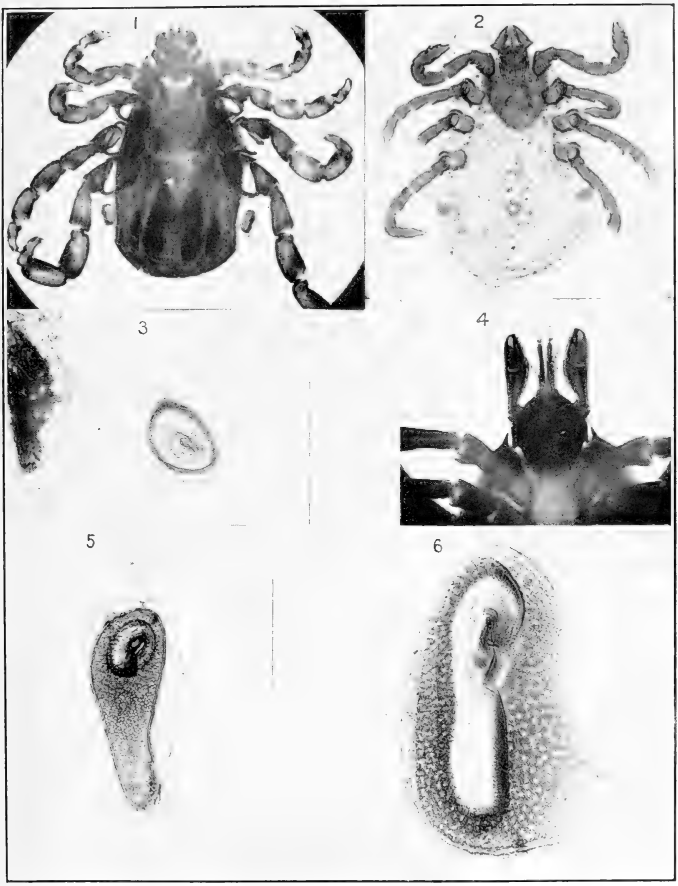
First eggs deposited.	Oviposition completed.	Period of oviposition.	Period from dropping.
		Days.	*Days.*
Apr. 2	May 5	34	37
Apr. 5	May 5	31	37
Apr. 7	May 1	25	33
Apr. 8	Apr. 27	20	29
Apr. 18	May 7	20	39
Average		26	35

In the above lot of five ticks collected March 29, as will be seen, the maximum period of oviposition was 34 days, the minimum 20, with an average of 26. The maximum number of eggs deposited in a lot of seven ticks collected July 22 was 1,270, the minimum 91, with an average of 636. An engorged tick collected April 30 commenced oviposition May 11, continuing for 12 days, as follows:

TABLE XI.—*Rate of oviposition in Rhipicephalus sp., from dog.*

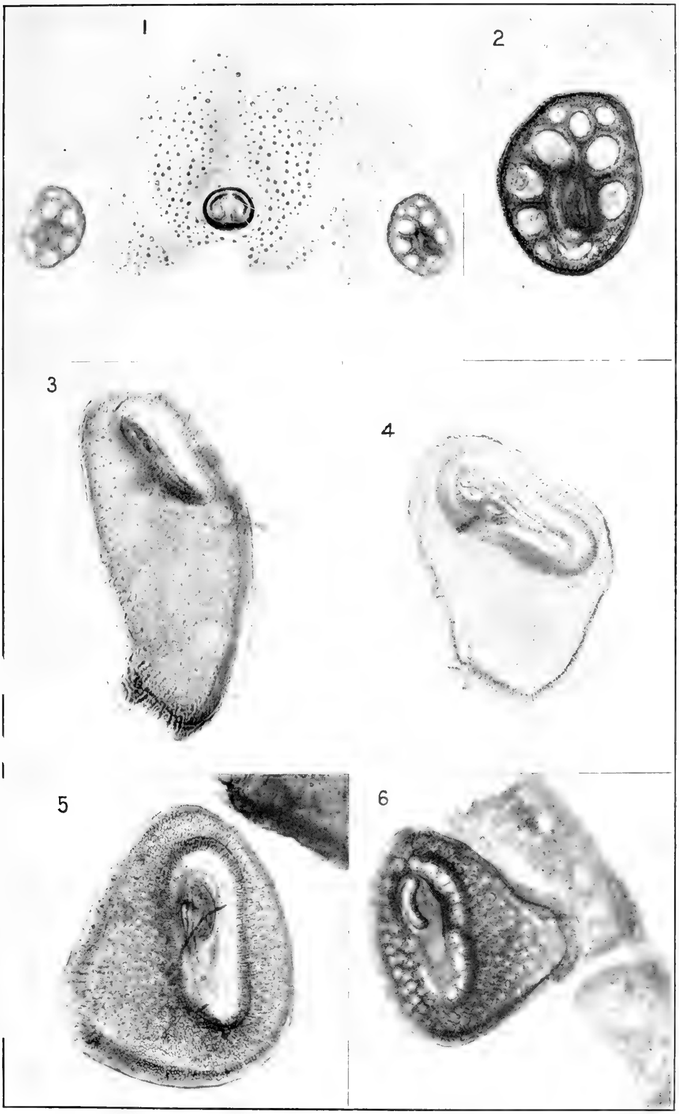
Number of eggs deposited—																Total.
May 10.	May 11.	May 12.	May 13.	May 14.	May 15.	May 16.	May 17.	May 18.	May 19.	May 20.	May 21.	May 22.	May 23.	May 24.	May 25.	
0	73	179	235	181	107	88	108	110	70	27	20	9	0	0	(*a*)	1,209

a Dead.



THE NORTH AMERICAN FEVER TICK AND OTHER SPECIES.

Fig. 1.—*Margaropus annulatus*, male. Fig. 2.—*Hæmaphysalis leporis-palustris*, female. Fig. 3.—Stigmal plate of *Margaropus annulatus*, male. Fig. 4.—Mouth parts of *Ixodes cookei*. Fig. 5.—Stigmal plate of *Rhipicephalus* sp., male. Fig. 6.—Stigmal plate of *Amblyomma maculatum*, female. Figs. 1, 2, much enlarged; fig. 4, more enlarged; figs. 3, 5, 6, highly magnified. (Original.)



STIGMAL PLATES OF TICKS.

Fig. 1.—Stigmal plates and anus of *Dermacentor nitens*, male. Fig. 2.—Stigmal plate of same. Fig. 3.—Stigmal plate of *Amblyomma cajennense*, male. Fig. 4.—Same, female. Fig. 5.—Stigmal plate of *Dermacentor variabilis*, female. Fig. 6.—Stigmal plate of *Dermacentor occidentalis*. Highly magnified. (Original.)

The incubation period of eggs deposited during the middle of April was 6 weeks and of those deposited at the end of that month, 33 days; seed ticks that emerged the first of June lived for 10 weeks, when kept in test tubes on sand.

Attempts were made to rear this species by placing seed ticks on dogs, but with poor success, as few seemed to attach. A dog was infested with seed ticks on May 29, but none could be found attached. On July 13, however, three adult ticks, two partially and one nearly fully engorged, were found between the toes on a front foot. One of the small ticks dropped July 14 and the engorged one on July 15. In the middle of October several males of this species appeared upon the dog, and these must have come from the above lot of seed ticks. They were found to change the location of their attachment from day to day. Our conclusion is that this species drops to the ground for both molts.

Genus MARGAROPUS.

Neumann stands alone in suppressing Margaropus (Boophilus) under Rhipicephalus. Although the two groups are closely related, it seems evident, not only from their structure but from their habits, that they form two distinct genera.

Neumann's latest arrangement of the forms is as follows:

R. (*M.*) *annulatus* (Say). Southern United States.

R. (*M.*) *annulatus* var. *australis* (Fuller). Australia, the Antilles, and South America.

R. (*M.*) *annulatus* var. *calcarata* (Birula). North Africa.

R. (*M.*) *annulatus* var. *decoloratus* (Koch). South Africa.

R. (*M.*) *annulatus* var. *caudata* Neumann. Japan.

R. (*M.*) *annulatus* var. *argentina* Neumann. Province of Buenos Ayres.

Neumann considers that *R.* (*M.*) *microplus* (Canest.) is very probably identical with *R.* (*M.*) *annulatus* var. *australis.*

The first portion of this bulletin deals with the sole North American representative of this genus, *M. annulatus* (see Pl. III, figs. 1, 3).

Genus DERMACENTOR.

This genus is characterized by the presence of cleft front coxæ in both sexes, the fourth pair of an immense size in the male but normal in the female. The structure of the stigmal plate furnishes valuable characters in specific determination in this genus as do the porose areas.

Salmon and Stiles in 1901 had but three species before them from the United States, which they identified as *D. electus* Koch (*variabilis* Say), *D. reticulatus* Neumann, and *D. variegatus* Neumann.

The species which they then listed as *D. reticulatus* Neumann is now considered by Doctor Stiles and Mr. Banks as Neumann's *D. occidentalis,* described from specimens collected in Sonoma County, California, and labeled *D. occidentalis* by Marx. The *D. reticulatus* of Salmon and Stiles is now considered by Banks as *albipictus* Packard. While *D. reticulatus* Fabricius is widely distributed, being found in Europe and Asia, so far as known it has not been taken in this country. *D. parumapertus,* described by Neumann in 1901 from 4 female specimens taken at Lakeside, Cal., labeled as taken on a man and in a chicken house; and *D. bifurcatus* Neumann, from a wild cat in Texas, described as Ixodes and later referred to the genus Dermacentor, seem to come close together, although they may be distinct species. According to Mr. Banks, *Ixodes nigrolineatus* Packard is a Dermacentor. To those referred to can now be added *Dermacentor nitens* Neumann, which has been collected by Mr. J. D. Mitchell, of this Bureau, making a total of 7 described species so far known to occur in the United States.

AMERICAN DOG OR WOOD TICK.

(*Dermacentor variabilis* Say.)

Synonymy (on the authority of Mr. Nathan Banks): *D. americanus* authors (not L.); *D. electus* Koch, 1844; *Ixodes albipictus* Pack. (1st Peabody Acad. Rept., p. 66, not Guide and Am. Nat.); *I. quinquestriatus* Fitch, 1871; *I. robertsoni* Fitch, 1871; *I. punctulatus* Say, 1821(?).

This species is distinguished by the finely punctate stigmal plate (see Pl. IV, fig. 5). It is widely distributed over the country, and has been taken commonly in northern and southern Texas and in Florida on the dog. In some sections of Texas *Amblyomma maculatum* and *Rhipicephalus* sp. are the common ticks on the dog, which is also the case with *I. scapularis* in Florida. Neumann records a male taken on a rabbit, *Lepus callotis,* by Dugès, at Guanajuato, Mexico. Cattle also serve as hosts.

Prof. H. A. Morgan records 7,378 eggs as deposited by a single tick between May 8 and 26. These eggs commenced hatching on August 20, an incubation period of 27 days. Our records include data on the deposition of eggs by a tick collected April 30, oviposition commencing May 8. The details follow:

TABLE XII. *Oviposition of Dermacentor variabilis.*

Number of eggs deposited—																					
May 8.	May 9.	May 10.	May 11.	May 12.	May 13.	May 14.	May 15.	May 16.	May 17.	May 18.	May 19.	May 20.	May 21.	May 22.	May 23.	May 24.	May 25.	May 26.	May 27.	May 28.	Total.
32	72	124	232	251	320	237	246	217	257	235	253	153	35	104	34	6	0	0	0	(a)	2802

a Dead.

In five lots of eggs deposited in April the incubation period varied from 37 to 43 days. Four lots deposited during May prior to the 10th hatched in 33 or 34 days. Seed ticks that hatched from eggs deposited May 10 lived until November 8 or 10, being alive November 6, but all were dead on November 10. The period of survival was thus six months from deposition.

Under summer temperature Prof. H. A. Morgan found engorgement of the adult to take place in from 5 to 8 days. He concludes that the larvæ and nymphs attach to mammals other than cattle, as the species has only been found on cattle in the adult stage, and attempts to cause seed ticks to attach failed.

NET TICK.

(*Dermacentor occidentalis* Neumann.)

This species (see Pl. IV, fig. 6) was received by Marx from Occidental, Cal. He determined it as a new species, labeling it *D. occidentalis*. Several writers have made use of this name, but it remained for Neumann to describe it for the first time in 1904, placing it as a variety of *D. reticulatus* Fab. Curtice in 1892 referred to it briefly as *D. americanum* (*variabilis*). It is now considered by Banks to be a distinct species and is the one referred to by Salmon and Stiles as *reticulatus*. The true *D. reticulatus* Fab. is not represented in our collections, although it may possibly be found to occur here when a thorough tick survey is made.

The species seems to be a western one, being found in the region of the Rocky Mountains especially. The Bureau of Entomology and Marx collections contain specimens from California, Washington, British Columbia, Colorado, New Mexico, and Texas. Salmon and Stiles also record specimens from Oklahoma and Tennessee. In a specimen taken from a deer skin at Kerrville, Tex., we have what is apparently this species, there being some doubt because of the poor condition of the individual. The recorded hosts include cattle, horse, sheep, deer, and man.

ELK TICK.

(*Dermacentor albipictus* Packard.)

Dermacentor albipictus Packard, Am. Nat., II, p. 559; Guide to the Study of Insects, 9th ed., p. 662. Not 1st Rept. Peabody Acad., p. 66. (See Banks, A Catalogue of the Acarina or Mites, <Proc. U. S. Nat. Mus., Vol. XXXII, 1907, p. 608.)

This species is found commonly on the wapiti or "elk" (*Cariacus canadensis*) in the States of Washington, Montana, Nebraska, Nevada, and New York. Salmon and Stiles report that game keepers on the reserve of the Blue Mountain Forest Association complain of its being very common on the wapiti and that it kills numbers of them.

They suggest the possibility of disease being transmitted by it. The specimens in the Bureau of Entomology collection from Nebraska were taken on the beaver.

TROPICAL HORSE TICK.

(*Dermacentor nitens* Neumann.)

This species is readily distinguished by the characteristic structure of the stigmal plate. (See Pl. IV, figs. 1, 2, and text figs. 5 and 6.) By collections by Mr. J. D. Mitchell from the ears of horses at Brownsville and at Harlingen, Tex., this species has been added to the list of ticks found in this country. The species was described by Neumann in 1897 from specimens in the Marx collection, locality unknown, and from specimens from San Domingo and Jamaica on the horse. In 1901 Neumann listed it from Guatemala, Venezuela, and Porto Rico.

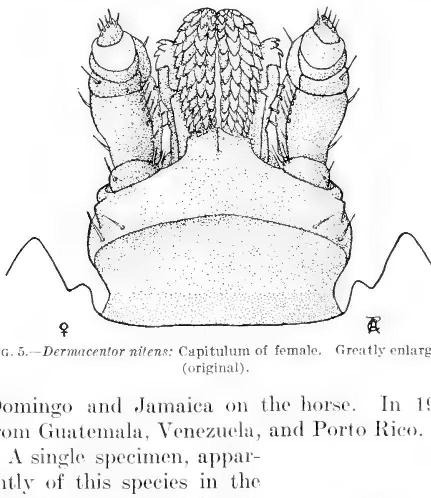


FIG. 5.—*Dermacentor nitens:* Capitulum of female. Greatly enlarged (original).

A single specimen, apparently of this species in the nymphal stage, was taken at Kerrville, Tex., by Mr. F. C. Pratt from a deer skin that had been removed in January.

Genus HÆMAPHYSALIS.

The ticks belonging to this genus may be readily recognized by the presence of conspicuous lateral prolongations on the second palpal segments. The eyes are absent; the coxæ of the male are all provided with spines, those of the female with small tubercular processes. Neumann mentions two species from North America, *H. leporis-palustris*

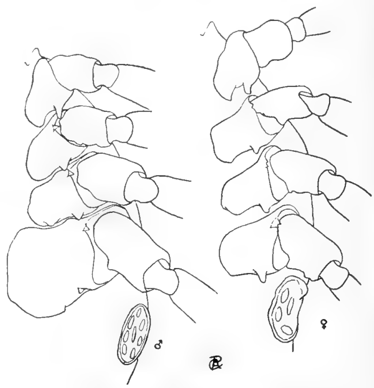


FIG. 6.—*Dermacentor nitens:* Coxæ of male and female. Greatly enlarged (original).

and *H. concinna*, but Banks informs us that he has not found the latter in this country. He recognizes *H. chordeilis* Packard as the form occurring in the eastern United States.

A South African species, *H. leachi*, has been determined by Lounsbury to transmit malignant jaundice of dogs. The larva and nymph both drop from the host to molt. Both engorge quickly, sometimes in less than 48 hours from the time they attach; usually, however, remaining from 65 to 75 hours.

RABBIT TICK.

(*Hæmaphysalis leporis-palustris* Packard).

Synonym: *Gonixodes rostralis* Dugès.

Packard described this species (see figs. 7, 8, and Pl. III, fig. 2) in 1869 from a female specimen collected at Fort Macon, N. C., on a

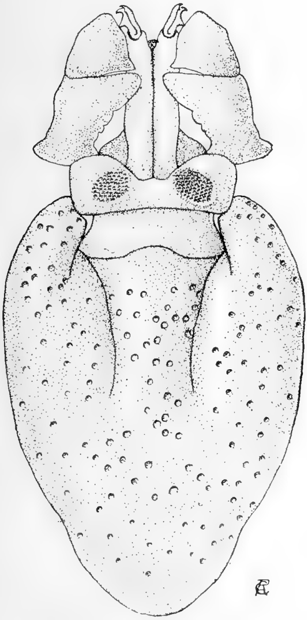


FIG. 7.—*Hæmaphysalis leporis-palustris:* Capitulum and scutum of female, dorsal view. Greatly enlarged (original).

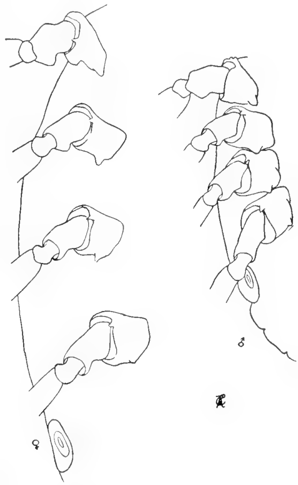


FIG. 8.—*Hæmaphysalis leporis-palustris:* Coxæ of male and female. Greatly enlarged (original).

rabbit, *Lepus palustris*. Marx reported the species as quite common in Kansas, Texas, and California. Dr. Cooper Curtice has taken an engorged female from a horse in Texas, and it has been collected in Mexico, the host not being given. Neumann mentions an engorged female in the museum of Paris labeled "from Brazil" and a

molting nymph taken on a Paradoxurus by Forbes in the Malaysian archipelago. Lahille reports it from Argentine Republic. During the past two years it has been collected in Texas by agents of the Bureau at eight different times from rabbits and hares. The species seems to be generally restricted to the genus Lepus, but two instances of other hosts having been recorded and these probably accidental. On the rabbit the ear seems a favorite place for attachment. As a more extensive collection of the tick is made it will undoubtedly be found to occur in a much greater territory than is now known. A few notes on the life history of this species have been made by us.

TABLE XIII.—*Oviposition of Hæmaphysalis leporis-palustris.*

Number of eggs deposited.														
May 20.	May 21.	May 22.	May 23.	May 24.	May 25.	May 26.	May 27.	May 28.	May 29.	May 30.	May 31.	June 1.	June 2–3.	Total.
260	110	228	146	131	98	72	63	4	0	0	0	0	(a)	1,112
0	0	2	39	8	7	3	0	0	(a)					57
0	47	70	48	43	29	22	14	12	14	7	13	7	(a)	326
0	0	0	0	7	17	22	21	13	4	9	5	1	(a)	99

[a] Dead.

TABLE XIV. *Period of incubation and longevity of Hæmaphysalis leporis-palustris.*

Eggs deposited.	Hatching commenced.	Minimum incubation period.	Remarks.
May 20-23......	June 20.......	31	March 5, dead.
May 24-29......	June 23.......	30	March 5, dead.
September 2-5.	September 26.	24	May 11, dead.

Subfamiiy IXODINÆ.

Three genera of this subfamily, Ceratixodes, Ixodes, and Amblyomma, are represented in the fauna of the United States. They may be readily distinguished. The Ixodes have long club-shaped palpi, the form of the third segment being typical of the genus (see Pl. III, fig. 4). The male and female have only the first coxæ provided with a spine of varying size; the anal groove surrounds the anus anteriorly, opening posteriorly; eyes are present. In Amblyomma the palpi are long but cylindrical; the male has a long spine on the first and fourth coxæ, while in the female only the first coxæ have spines, the others possessing tubercles; the anal groove surrounds the anus posteriorly and opens anteriorly. Ceratixodes, with pointed palpi, occurs on sea birds.

Genus IXODES.

(The Castor Bean Ticks.)

Previous to 1796 all ticks were placed under the Linnæan genus Acarus. In that year Latreille erected the genus Ixodes, giving *I. ricinus* as the type species. For many years following all ticks

were described as belonging to this genus, as is the case with the species of Say, Fitch, and Packard.

Of the genera represented in the United States this has the largest number of species. Fourteen are recognized, as follows:[a]

I. ricinus L., *I. frontalis* Panzer, *I. scapularis* Say, *I. fuscus* Say, *I. brunneus* Koch, *I. uriæ* White, *I. cookei* Packard (Synonyms: *I. cruciarius* Fitch, and *I. hexagonus* of S. & S., on the authority of Nathan Banks), *I. arcticus* Osb., *I. diversifossus* Neum., *I. dentatus* Neum., *I. angustus* Neum., *I. inchoatus* Neum., *I. sculptus* Neum., and *I. californicus* Banks.

Of these, four have been taken in Texas by agents of this Bureau—*ricinus*, *cookei*, *scapularis*, and *sculptus*.

Comparatively little is known of the life cycle of the species of Ixodes. The work of E. G. Wheler on "Louping Ill and the Grass Tick" (*I. ricinus*) is about all that has been done. It seems probable that all species drop to molt.

As Mally ascertained to be the case with *I. pilosus* in South Africa, we have found engorged females of *I. scapularis* to dry up in captivity before ovipositing. From Wheler's studies and our experience moisture seems to be a necessity in order that molting may take place.

The longevity of the larvæ of ticks of this genus must be exceptional, even when some of the long-lived species of other genera are considered. Wheler mentions larvæ (*I. plumbeus?*) which hatched on October 9, 1898, from eggs laid in August, that lived until the beginning of August, 1899, or about 10 months. They were kept in a bottle with a sprig of moss and some damp sand.

AMERICAN CASTOR BEAN TICK.

(*Ixodes cookei* Packard.)

Synonymy (on the authority of Nathan Banks): *Ixodes cruciarius* Fitch; *I. hexagonus* S. & S. (not *hexagonus* Leach, 1815); *I. hexagonus* var. *longispinosa* Neum.

This species (Pl. III, fig. 4) was described by Packard from specimens on a woodchuck, *Arctomys monax*, at Salem, Mass. Neumann, in 1899, placed the American form with the European *I. hexagonus*, but in 1901 he separated the two as varieties. Salmon and Stiles, in 1901, followed Neumann, who at that time had all their specimens. Banks has examined the National Museum material and considers *longispinosa* the same as *I. cookei* of Packard, but states that there may be a true *hexagonus* in this country, though he has not seen it.

[a] According to Nathan Banks, *I. nigrolineatus* Packard is a Dermacentor.

We have taken this species in Texas from a goat, a raccoon, and a skunk. Neumann records it as taken in the United States from the otter, mink (*Putorius vison*), sheep (Texas), spermophile, domestic cat (Maine), fox (Colorado), weasel, porcupine, and marmot.

EUROPEAN CASTOR BEAN TICK.

(*Ixodes ricinus* Linnæus.)

From its general distribution throughout Europe this species has been called the European castor bean tick.

Mr. Banks informs us that in this species the front tarsi are longer than in any other species of the genus found in the United States; that in structure it is very similar to *I. scapularis*, but the porose areas are larger and closer together and the scutum is more angulate on the sides than in that species. Neumann, in his list of hosts of the adult stage, includes sheep, goat, cattle, horse, stag, roebuck, dog, cat, fox, ferret, hedgehog, and man; the nymphs and larvæ having occasionally been found on lizards, birds, hares, rabbits, squirrels, polecats, ferrets, hedgehogs, mules, bats, and mice. In the United States he lists it from Maryland, "Carolina," Florida, California, Kansas, and Texas, on *Lepus sylvaticus*, *Felis pardalis*, cattle, opossum, gray fox, panther, and wild cat. While we have expected to find it frequently in Texas, in but a single instance has it been taken. This was by Mr. F. C. Pratt, at Mountain Home, from a dog. In Louisiana Prof. H. A. Morgan reports it as found on mink in all its stages, but on cattle only in the adult stage.

Although this is an old and widely distributed species, but little study has been made of its life history, that of E. G. Wheler, of England, in 1899, standing practically alone. His most valuable studies were made to determine the relation of the tick to "louping ill" of sheep, with which, in the light of present knowledge, it seems to have only an accidental connection.[a] The following is the substance of Wheler's observations made in England and published in 1899:

The adult females are readily recognized before they become distended by their deep-red bodies, dark-brown legs, shield, and other points. The males are of a uniform dark brown. A record of 2,050 eggs from a single female is given, and a very interesting account of the remarkable process of oviposition. Larvæ, upon finding a host, attach, and remain for about 2 days, by which time they are distended, black, and globular. Fully distended larvæ received February 7 and kept in a bottle became hard, dry, and torpid, but on April 29, after 11 weeks, were found to have changed into nymphs and resumed active habits. After molting the nymph takes up its position on the herbage, just as the larvæ had done, for a chance of attachment to a host.

[a] Journal of the Royal Agricultural Society of England, Vol. X, pt. 4.

Whereas adults seem to confine themselves mostly to sheep, cattle, and deer, the larvæ and nymphs attach themselves very readily to various hosts, such as horses, dogs, and human beings. About a dozen distended nymphs taken from sheep May 29, though kept moist, had the same dry appearance as the larvæ, as before described. These molted about July 19, about 11 weeks after removal from the host. For some time previous they had appeared dead, no motion of the extended legs being perceptible. Of these about half proved to be males. About 10 days passed before the sexes attained their proper color and strength. On reaching the adult stage both males and females again wait on herbage for a passing host. At this time, as well as after distention of the female on the host, an action which appears to be sexual intercourse freely takes place even in confinement. The rostrum and other mouth parts of the male are inserted in the genital opening of the female, which is situated between the bases of the posterior pair of legs. On the host the females gradually distend, and in the course of so doing vary much in color and appearance, so much so in this case that it is difficult to believe that they are of the same species. Of the exact periods of engorgement we are not informed. Under unfavorable conditions larvæ have been kept alive for 4 months. Nymphs were kept alive for 6 months and adult males and females for 4 months, being still alive at the time of writing (1899). Without moisture, when kept in a dry empty bottle, neither larvæ, nymphs, nor adults survived more than 2 or 3 days. Females exposed to 25° F. for a night were found to be but little affected.

This species, according to recent investigations of Kossel and others in Germany, transmits European piroplasmosis of cattle. The fact that the organism *Piroplasma bigeminum* is the same as is found in this country lends great interest to investigations to determine whether *I. ricinus* may not transmit Texas fever in the United States.

BLACK-LEGGED TICK.

(*Ixodes scapularis* Say.)

Say states that this species is rather common in forests, and is frequently found attached to different animals. Neumann has not recognized the species, but Banks has identified it with a form common in some parts of the South. In Texas we have collected it from deer and dogs, and in Florida from dogs. In the latter State it seems to be very common, and was taken at Hawthorn, Orlando, and Fort Myers.

This species is remarkable for the size that the engorged seed tick reaches. These are as large or larger than the engorged nymph of *Margaropus annulatus*, although the adult is not as large as the adult Margaropus. Large numbers of seed ticks and adults have been

taken on dogs, though as yet not a single nymph. This suggests the remote possibility that the species may pass from the larval to the adult stage at a single molt.

SCULPTURED TICK.

(*Ixodes sculptus* Neumann.)

This species was described in 1904 from a female specimen taken with a female *I. ricinus* in the Santa Cruz Mountains of California. So far as known it had not been taken since until Mr. F. C. Pratt collected it on prairie dogs at Sherwood, Tex., November 2, 1906. More extensive collection will undoubtedly show a wider distribution than is now known.

Genus AMBLYOMMA.

The species of the genus Amblyomma are distinguished by the palpi, which are long and cylindrical. The male has the first and fourth coxæ armed with a long spine; the female has only the first coxæ with a spine, the others with tubercles. As far as known all the species drop from the host for each molt. Lounsbury has found *Amblyomma hebræum* to be the transmitter of heartwater in cattle, sheep, and goats, and has carefully worked out its life history.

The genus is represented in the United States by four species—*americanum*, *cajennense*, *maculatum*, and *tuberculatum*. A fifth species, *A. multipunctum*, is described by Neumann from two specimens taken on a tapir and an antelope (*Dicranocerus furcatus*) in "North America." These are reported as collected by Donckier. As no species of tapir is found north of Nicaragua it seems probable that *A. multipunctum* must have been taken from that section of North America.

TABLE FOR SEPARATING THE SPECIES OF AMBLYOMMA OF THE UNITED STATES.

(Adapted from Neumann.)

MALES.

1. Marginal groove extending around the posterior border........................2
   Marginal groove not extending around the posterior border........*A. tuberculatum.*
2. Coxæ I bicuspid........................3
   Coxæ I armed with one long spine........................*A. maculatum.*
3. Punctations of scutum lacking from the triangular projections, flat, radiating on posterior half........................*A. cajennense.*
   Punctations distributed over entire surface of scutum........................*A. americanum.*

FEMALES.

1. Coxæ I bicuspid........................2
   Coxæ I armed with one very long spine........................*A. maculatum.*
2. Scutum triangular, posterior-lateral borders nearly straight........................3
   Scutum cordiform, oval, or pentagonal, posterior-lateral borders convex. *A. tuberculatum.*
3. Eyes in front of anterior third of scutum........................*A. cajennense.*
   Eyes at plane of or behind anterior third of scutum........................*A. americanum.*

LONE STAR TICK.

(*Amblyomma americanum* Linnæus.)

The lone star tick derives its name from the bright-silvery spot on the scutum of the female. It is widely distributed, having been reported from Labrador to Florida, and also from Guatemala and Brazil. After *Margaropus annulatus*, it is the most important tick in the United States. Though found more commonly on cattle we have taken it from man, horse, mule, dog, goat, hog, deer, squirrel, and wolf, and it appears to attack mammals generally. In portions of Louisiana and Texas it becomes a pest of considerable importance to moss gatherers and other persons who spend much time in the forests. It has been repeatedly taken in Texas during the summer of 1906 on the clothes or attached to the body of agents of the Bureau. Packard mentions a case in which one buried itself in the arm of a young girl, producing a raised tumor.

In May it was found on a herd of dairy cows near Dallas in large numbers, though only an occasional specimen of *Margaropus annulatus* was present. The proprietor of the dairy stated that they were very annoying through their attaching to milkers. Mr. J. D. Mitchell has found it in the vicinity of Kerrville and Llano, Tex., to be the most important species, being much more numerous than the fever tick. In that region the cattle suffer greatly from it. Its abundance seems to be due to the large numbers of sheep and goats kept in that section. These serve as hosts, spreading it broadcast, at the same time reducing the bunches of *Margaropus annulatus* seed ticks.

TABLE XV.—*Oviposition of Amblyomma americanum.*

Collected—	Oviposition.		Period of oviposition.	Dropping to end of oviposition.	Number of eggs deposited.
	From—	To—			
			Days.	*Days.*	
Mar. 26	Apr. 5	Apr. 20	16	26	....
Apr. 27	May 5	May 18	14	22	2,444
May 2	May 13	May 21	9	20	984
May 15	May 25	June 5	12	22	2,508
May 19	May 27	June 7	12	20	5,040
Do	do	June 6	11	19	2,659
Do	do	June 9	14	22	1,736
Do	do	June 5	10	18	950
Do	do	June 10	15	23	1,510
Do	do	June 7	12	20	1,306
Total	....	....	107	....	19,137
Average	....	....	12.5	21.2	2,126

Our records regarding oviposition, as shown in the above table, are from 10 engorged ticks. It will be seen that the maximum number of eggs deposited by an individual was 5,040, deposition continuing for 12 days; the minimum, 950, with a deposition period of 10 days; an average of 2,126 eggs deposited in 12 days. Morgan records as many as 6,519 eggs.

TABLE XVI.—*Incubation and longevity of Amblyomma americanum.*

Eggs deposited.	Commenced to hatch.	Minimum incubation period.	Seed ticks all dead.	Period of— Oviposition to death.	Period of— Hatching to death.
		Days.		*Days.*	*Days.*
Apr. 15-17	June 3	50	Sept. 13	152	103
Apr. 25	June 5	42			
Apr. 28	June 8	42			
May 28 and 29	July 1	35	Nov. 8 [a]	163	129+
May 30 and 31	July 1	33	Nov. 22	177	145

[a] One or more alive.

From the above table it will be seen that the incubation period in April and May is about 7 weeks. Eggs deposited in the latter part of May hatched in 5 weeks.

Prof. H. A. Morgan has found some specimens to pass the first molt on the host, dropping in about 10 days following that molt, or just previous to the second molt. The greater number dropped in from 4 to 7 days. The molting of the nymph was found to last 6 weeks. Engorgement of the adult in March and April occupied from 7 to 11 days.

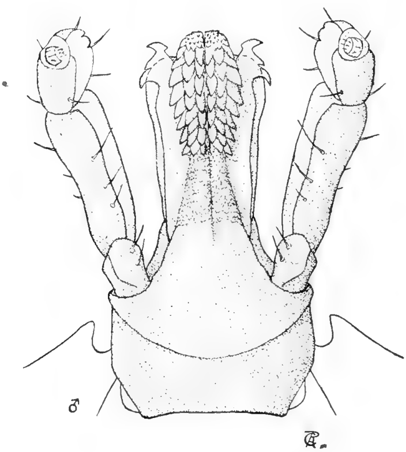


FIG. 9.—*Amblyomma cajennense:* Mouth parts of male. Greatly enlarged (original).

The resistance of the female to water seems to be similar to that of the fever tick. Seven females were submerged for 18 hours, all becoming active following removal from the water. The next day all were again submerged for 45 hours. Only one, an unengorged specimen, survived.

In the adult stage both sexes will reattach, as seems probable in the larval and nymphal stages.

Mr. Mitchell has observed adults on grass in the act of copulation.

CAYENNE TICK.

(*Amblyomma cajennense* Fab.)

Synonyms: *I. crenatum* Say (Banks), *A. mixtum* Koch (Banks), *I. herreræ* Dugès (Neum.), *A. sculptus* Berlese (Neum.).

This species was described from Cayenne in 1794, no host being

given. The writers' opinion of the specific identity of specimens from Venezuela, on cattle, with Texas specimens, on horse and peccary, is confirmed by Mr. Banks. The species may be distinguished from *maculatum* readily by the characters given in the table. (See also figs. 9 and 10 and Pl. IV, figs. 3, 4.)

The species has been reported from, and seems to be generally distributed through Mexico and Central America. It has been reported from Colombia, Venezuela, Brazil, and Argentine Republic in South America. Neumann also reports it from Cuba and Jamaica. In Texas Mr. J. D. Mitchell has taken it in Live Oak County from the peccary and horse. Mr. Banks reports specimens from Louisiana, Missouri, and Florida. In addition to the hosts mentioned it has been reported from toad (*Bufo agua*), capybara (*Hydrochærus capybara*), an ant-eater, and man.

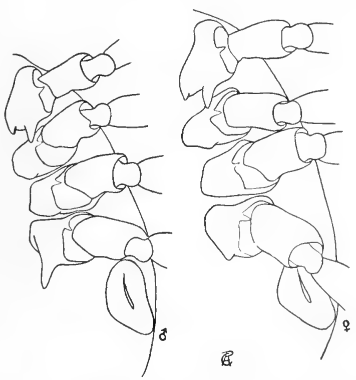


FIG. 10.—*Amblyomma cajennense:* Coxæ of male and female. Greatly enlarged (original).

Stoll, in the Biologia Centrali-Americana, states that this species is the most common of all Ixodidæ in Central America, and gives some information concerning its habits. He has never found the male in a parasitic state, but has found it free on grass and bushes in Guatemala. The female, which he states abounds in the woods and fields on grass and bushes, is occasionally brushed off by horses, cattle, or dogs, and even man. It adheres tenaciously to the skin, remaining when undisturbed for several days until filled with blood. If forcibly removed, the beak breaks off and remains in the wound, causing a disagreeable and sometimes painful inflammation. The young, which are distinguished by the inhabitants of Guatemala by the name of "mostacilla," hang to the grass in clusters of thousands, especially during the dry seasons. By their creeping on the skin and frequent biting they form one of the greatest plagues of travelers.

In a letter accompanying specimens of this species from Venezuela the writers are informed that the ticks do great damage by producing fever in cattle, which become weak and in many cases die. It hardly seems possible that the malady can be Texas fever; nevertheless this species may possibly transmit some disease.

TABLE XVII.—*Record of deposition of an engorged tick, Amblyomma cajennense, collected on peccary April 29.*

Number of eggs deposited—																							
May 9.	May 10.	May 11.	May 12.	May 13.	May 14.	May 15.	May 16.	May 17.	May 18.	May 19.	May 20.	May 21.	May 22.	May 23.	May 24.	May 25.	May 26.	May 27.	May 28.	May 29.	May 30.	May 31.	Total
67	85	212	278	44	259	289	213	336	307	206	119	60	68	33	33	23	11	3	4	0	0(*a*)		2,650

a Dead.

It will be seen that oviposition continued for 20 days from May 9, a total of 2,650 eggs being deposited. Eggs deposited May 14 commenced hatching June 21, an incubation period of 38 days. Two seed ticks from eggs deposited May 14–25 were alive November 6, a period of more than 5 months from deposition. The fact that this prolonged survival included summer months shows remarkable vitality in the seed ticks of this species. Seed ticks of *Margaropus annulatus* seldom survive over 3 months in the summer.

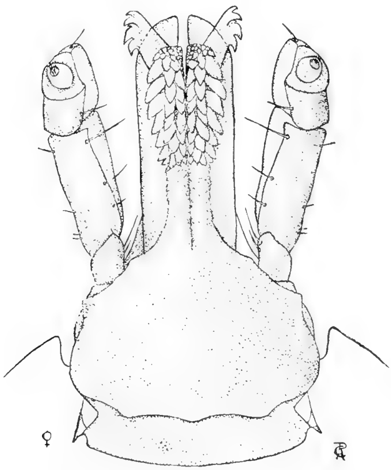


FIG. 11.—*Amblyomma maculatum:* Mouth parts of female. Greatly enlarged (original).

GULF COAST TICK.

(*Amblyomma maculatum* Koch.)

Synonyms: *A. tigrinum* Koch, *A. tenellum* Koch, *A. rubripes* Koch, *A. ovatum* Koch, *A. triste* Koch, *A. complanatum* Berlese (the preceding on the authority of Neumann), *Dermacentor occidentalis* Marx of Niles (Morgan).

This species was described by Koch in 1844 from "Carolina," no host being given. Prof. H. A. Morgan calls our attention to the fact that it was referred to as *Dermacentor occidentalis* Marx by Niles.[a]

It seems to be the common species along the Gulf coast of Louisiana and Texas. (See figs. 11, 12, 13, and Pl. III, fig. 6.) It was taken by Mr. J. D. Mitchell of this Bureau from cattle, horses, dogs, and man in Cameron Parish, La., and Calhoun, Jackson, and Victoria counties, Tex. In the Marx collection there is a male specimen

[a] Bul. Va. Agric. Exp. Sta., VII, No. 3, pp. 28, 29, Pl. IV.

recorded as taken from cattle at Memphis, Tenn. It seems quite probable that the animal from which the tick was collected had been bred in the Coast section. There are also several specimens in the Marx collection taken in Texas. Neumann reports it from Paraguay, Uruguay, Brazil, Mexico, and in the United States from California, Texas, and Tennessee, the latter based upon the tick before mentioned as collected at Memphis. He mentions 2 males and 1 female as being taken on a coleopteron, *Cercus campestris*, at Buenos Aires, Argentina. Lahille reports it from Argentine Republic, where the favorite host is the dog. He mentions the fact that it is used by the Indians as a leech in certain cases of inflammation.

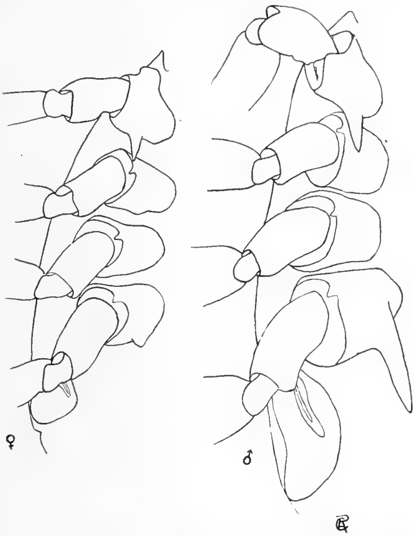


FIG. 12.—*Amblyomma maculatum:* Coxæ of male and female. Greatly enlarged (original).

The male is especially large, much more so and more elongate than either *A. cajennense* or *A. americanum*. Mr. Mitchell reports that while he has observed the sexes in close proximity on the animals he has as yet to find them *in coitu*. He has frequently noticed them to copulate after being removed from the animal. However, in Argentina, Lahille states that several males are usually found attached in the immediate vicinity of each female. Mr. Mitchell states that on one occasion he found 7 females clustered on a cow between the ear and the horn with no male near. In another case he found a cluster of 5 females on the neck of a dog with no male in the immediate vicinity. He has also seen instances where as

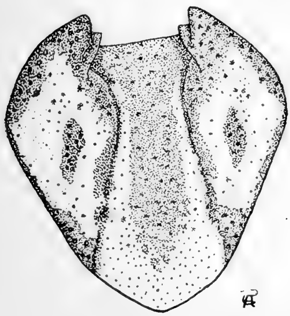


FIG. 13.—*Amblyomma maculatum:* Scutum of female. Greatly enlarged (original).

many as 5 males were located very close together without any females, and other cases on various parts in which both sexes were found together. This species is very firmly attached to the host. While *Rhipicephalus* sp. can be removed easily *A. maculatum* can not be removed without evident pain.

Attempts were made to rear the species upon dogs. On October 11 seed ticks were placed upon two small dogs. Eight were found attached on the 15th. For the first five or six days after attachment the seed ticks increase slowly in size, remaining of a light color; then in a few hours they seem suddenly to engorge with blood. The color of the body becomes purplish and afterwards still darker. On the fifth day from placing seed ticks on the dogs 8 were found still light in color and 1 dark. On the sixth day 2 were taken that had just detached themselves, leaving 2 dark and 4 light on the host. On the seventh day 3 were found to have dropped during the night; 2 dropped and the remaining 1 engorged during the day. On October 19 the eighth tick was found to have dropped during the night, making a minimum period of 5 days and a maximum period of 8 days for attachment of larval stage.

Several of the engorged larvæ were kept on moist sand to molt, but shriveled and died.

The incubation period for eggs deposited from the 1st to the 11th of September varied from 26 to 31 days. Seed ticks from these eggs were still alive on March 1, 1907.

LAND TURTLE TICK.

(*Amblyomma tuberculatum* Marx.)

This species was described by Marx in 1894 from specimens collected by Hubbard at Crescent City, Fla., from the Florida land turtle, *Gopherus* (*Xerobates*) *polyphemus*. Neumann reports a male specimen from Cuba.

We have received 3 specimens collected in February, 1907, by Dr. A. W. Morrill in Florida on a land turtle (*Gopherus* sp.), presumably the same as the host of the original specimens.

BIBLIOGRAPHY.

No attempt has been made to make this bibliography complete. In Section A, relating to the cattle tick of North America and the problems caused by it, the literature is scattered through many experiment station bulletins, veterinary journals, bulletins of the Department of Agriculture, and other publications. Only the more important are included. In Section B, relating to foreign disease-

transmitting ticks, the literature is found for the most part in the governmental publications of South Africa and Australia, although recently important memoirs have been issued in Germany and France. As in the preceding section, we give only the more important publications that are now available. For a very complete bibliography of this subject down to 1903, containing 221 titles, see A. Schmidt below. In Section C, relating to ticks as transmitters of human diseases, there is at present but a scanty literature. It is practically all referred to by us. In Section D, relating more particularly to the classification of ticks, practically all of the works dealing with North American species are listed, together with the more important foreign publications. For a more extended list, see Salmon and Stiles, 1901, below.

SECTION A.

Relating to the North American Fever-Tick Problem.

Butler, Tait.

1902.—The breeds of beef cattle and beef production in North Carolina <N. C. State Bd. Agr., bul. 23, no. 7.

Pages 48-51 deal with: "Cattle tick an obstacle to the development of the cattle industry."

1903.—Report of State Veterinarian in Rept. Comm. Agr. N. C. for 1902, pp. 40–47.

Regarding the cattle quarantine, the extermination of the cattle tick, losses from tick fever, and the tick an obstacle to the improvement of the quality of the cattle of the State.

1903.—The cattle tick and its relation to the cattle industry of North Carolina <N. C. State Bd. Agr., bul. 24, no. 5, pp. 28, figs. 2.

1903.—The cattle tick and the quarantine restrictions <N. C. State Bd. Agr., bul. 24, no. 10, pp. 30–37.

1906.—Progress made in exterminating the fever tick (*Boophilus annulatus*) in North Carolina <N. C. Dept. of Agr. circular (unnumbered) issued January 1, 1906, pp. 4. Reprinted in part in Farm and Ranch, vol. 25, no. 15, p. 7, April 14.

This circular deals with the most successful work that has been done in the practical eradication of the cattle tick.

Connaway, J. W.

1897.—Texas fever or acclimation fever <Mo. Agr. Exp. Sta., bul. 37, pp. 81–139, figs. 11, April.

Connaway, J. W., and M. Francis.

1899.—Texas fever <Mo. Agr. Exp. Sta., bul. 48, pp. 66, figs. 11.

Curtice, Cooper.

1891.—The biology of the cattle tick <Journ. Comp. Med. and Vet. Arch., vol. 12, no. 7, pp. 313–319, July.

1892.—About cattle ticks <Journ. Comp. Med. and Vet. Arch., January.

This and the preceding paper were issued together with independent continuous pagination.

1892.—The cattle tick <Texas Agr. Exp. Sta., bul. 24, pp. 237–252, 2 pls., December. Appendix on preventive measures by M. Francis. Abstract, Insect Life, vol. 5, p. 294.

This bulletin gave the first details of the life history of the cattle tick. It was a pioneer work the value of which has been appreciated by all subsequent workers.

CURTICE, COOPER—Continued.

1896.—On the extermination of the cattle tick and the disease spread by it Journ. Comp. Med. and Vet. Arch., vol. 17, pp. 649–655.

On page 655 Doctor Curtice gives the first reference we have found to the possibility of totally exterminating the cattle tick from the United States. "I look most eagerly for the cleansing of even a certain portion of the infected territory under the direct intention of man, for it opens the way to pushing the ticks back to the Spanish isles and Mexico, and liberating cattle from disease and pests and the farmer from untold money losses. Let your war cry be: Death to the ticks!"

1897.—The cattle tick and what may be done to prevent it <The Southern Planter, vol. 58, no. 1, pp. 24–27, January.

This paper contains the original suggestion of the pasture eradication and feed-lot systems of tick eradication.

1897.—Texas fever <The Southern Planter, vol. 58, no. 3, pp. 116–117, March.

1899.—Cattle quarantine, ticks and distemper <N. C. State Bd. Agr., bul. (unnumbered), July 1.

1899.—Cattle quarantine line <N. C. Agr. Exp. Sta., spec. bul. 52, pp. 1-28.

1905.—The cattle-tick plague <The Southern Planter, vol. 66, no. 5, pp. 376–378, May.

A report of progress in extermination and a continuation of the two articles published in the above Journal October, 1896, and January, 1897.

DALRYMPLE, W. H., H. A. MORGAN, and W. R. DODSON.

1898.—Cattle tick and Texas fever <La. Agr. Exp. Sta., bul. 51, pp. 230–282, figs. 2, pls. i–vii.

Detailed account of many experiments relating to the life history of *Margaropus annulatus*. Includes studies of the effects of water, heat, cold, and light on the eggs, seed ticks, and adults, and much information on pasture eradication. The plates are excellent. This publication adds greatly to the data furnished by Doctor Curtice in Texas Bulletin 24.

1899.—Immunization against Texas fever by blood inoculation <La. Agr. Exp. Sta., bul. 57, ser. 2, pp. 146–185, pls. 2, chts. 3, figs. 3.

DINWIDDIE, R. R.

1892.—Parasitism of domesticated animals <Ark. Agr. Exp. Sta., bul. 20, pp. 14–31.

Treats of mites, cattle ticks, etc.

1896.—Texas cattle fever in various localities <Ark. Agr. Exp. Sta., report, 1896, pp. 36–40.

A reprint from bulletin 40 of the station.

1898.—Methods of combating communicable diseases of farm animals <Ark. Agr. Exp. Sta., bul. 51, pp. 35–46, May.

FRANCIS, M.

1889.—Report of the veterinarian, Tex. Agr. Exp. Sta., second annual report, 1889, pp. 55–60.

A brief account of the southern cattle plague and its treatment, with notes on joint experiments by the Texas and Missouri Stations.

1892.—The cattle tick, preventive measures for farm and range use <Tex. Agr. Exp. Sta., bul. 24, pp. 253–256, fig. 1, December.

1894.—Veterinary Science <Tex. Agr. Exp. Sta., bul. 30, pp. 436–458, March.

Treats of animal parasites, device for destroying ticks, and influence of ticks in the dissemination of Texas cattle fever.

FRANCIS, M., and J. W. CONNAWAY.

1899.—Texas fever <Tex. Agr. Exp. Sta., bul. 53, pp. 53–106, figs. 13.

LEWIS, L. L.

1897.—Texas fever <Okla. Agr. Exp. Sta., bul. 27, pp. 8–15, fig. 1, June.

LEWIS, L. L.—Continued.

1899.—Texas fever. An account of experiments <Okla. Agr. Exp. Sta., bul. 39, pp. 28, figs. 5, May.

1900.—Means of preventing Texas fever <Okla. Agr. Exp. Sta., report, 1900, pp. 26–28.

MAYER, AUGUST.

1906.—The cattle tick in its relation to southern agriculture <U. S. Dept. Agric., farmers' bul. No. 261, pp. 1–22.

An excellent essay on the broad aspects of the tick problem.

MAYO, N. S.

1897.—Texas fever <Kans. Agr. Exp. Sta., bul. 69, pp. 124–134, June.

McCULLOCH, C.

1899.—The prevention of Texas cattle fever and the amended laws controlling contagious and infectious diseases <Va. Agr. Exp. Sta., bul. 104, pp. 167–180, September.

MELVIN, A. D.

1906.—How to get rid of cattle ticks <U. S. D. A., Bur. A. I., cir. 97, pp. 1–4, 1 pl.

Deals with the hand-picking and greasing, the tie-rope or picketing, and the two-field methods.

MILLER, W. McC. N.

1895.—Texas cattle fever <Nev. Agr. Exp. Sta., bul. 31, pp. 11, December.

MOHLER, J. R.

1906.—Texas fever (otherwise known as tick fever, splenetic fever, or southern cattle fever), with methods for its prevention <U. S. D. A., Bur. A. I., bul. 78, pp. 1–48, pls. 3, figs. 3.

A comprehensive treatment of the whole subject, including symptoms, pathology, therapeutics, and methods of tick eradication.

1906.—Texas or tick fever and its prevention <U. S. D. A., farmers' bul. 258, pp. 1–46, figs. 1–6.

This is a somewhat condensed re-edition of the preceding.

MORGAN, H. A.

1899.—Ticks and Texas fever <La. Agr. Exp. Sta., bul. 56, pp. 128–141, pls. 9, September.

This is the only American work on the life history of species other than *Margaropus annulatus*. It deals with *Amblyomma americanum*, *Dermacentor variabilis* (*electus*), both of which were found to be nonpathogenic as far as splenetic fever is concerned, and *Ixodes ricinus*. Many details of life history are given. The plates are most valuable. Marx's paper on the classification of the Ixodidæ is reprinted as a part of this bulletin.

The starving-out method of eradication is again emphasized. (See Dalrymple, Morgan, and Dodson, 1898.)

1903.—How can we exterminate the cattle tick? <Proc. La. State Agr. Soc. and Stockbreeders' Assn., 1903, pp. 77–79.

Emphasizes the necessity for cooperation among the farmers.

1903.—The cattle-tick situation <Proc. Soc. Prom. Agr. Sci., 1903, pp. 72–74.

Notes are given on the life history of the cattle tick.

1905.—Texas fever cattle tick: pasture methods of eradication <Bul. of Agr. Exp. Sta. Univ. Tenn., vol. 18, no. 1, pp. 1–10, figs. 3.

Also published as bul. 82 (second series), La. Agr. Exp. Sta., pp. 1–15.

This publication urges the feasibility of the practical application of a knowledge of the life history of the cattle tick in feed-lot and pasture-eradication systems of eradication and centered public attention. It gives full details as to procedure.

See also Dalrymple, Morgan, and Dodson.

NEWELL, WILMON, and DOUGHERTY, M. S.

1906.—The cattle tick. Studies of the egg and seed-tick stages. A simple method of eradicating the tick <La. Crop Pest Comm., cir. 10, pp. 1–32, figs. 1–8.

Contains records of very careful work on the egg and seed-tick stages. The practical importance of the work is well demonstrated.

NILES, E. P.

1897.—The cattle tick in Virginia <Va. Agr. Exp. Sta., bul. 76, pp. 45–50, May. Southern Planter, July, 1898, pp. 326–327.

1898.—A preliminary study of ticks <Va. Agr. Exp. Sta., bul. 86, pp. 25–30, 4 pls., March.

NÖRGAARD, VICTOR A.

1898.—Cattle dipping, experimental and practical <U. S. D. A., yearbook, 1898, pp. 453–472.

Experiments, principally with saturated solutions of sulphur in extra dynamo oil

RANSOM, B. H.

1906.—Some unusual host relations of the Texas fever tick <U. S. D. A., Bur. A. I., cir. 98, pp. 1–8.

Details experiments in attempting to cause *Margaropus annulatus* to develop on horses, mules, asses, rabbits, dogs, and cats. On the last a specimen developed to the adult stage, but did not engorge. Shows that under certain conditions the cattle tick can reattach after being artificially removed. Refers to recent European investigations that show that *Ixodes ricinus* transmits European piroplasmosis of cattle, and suggests the possibility that *Margaropus annulatus* may transmit its disease in the nymphal or adult states.

REDDING, R. J.

1889.—Cattle ticks and Texas fever <Ga. Agr. Exp. Sta., bul. 49, pp. 228–229.

RILEY, C. V., and L. O. HOWARD.

1899.—The Texas cattle tick <Insect Life, vol. 2, July, 1889, p. 20. Habits and remedies.

ROBERT, J. C.

1897.—Acclimation fever, or Texas fever <Miss. Agr. Exp. Sta., bul. 42, pp. 32, figs. 4.

1901.—Texas fever <Miss. Agr. Exp. Sta., bul. 69, pp. 1–15, figs. 4, November.

1902.—Tick fever or murrain in Southern cattle (commonly termed Texas fever) <Miss. Agr. Exp. Sta., bul. 73, pp. 1–24, figs. 2, July.

SALMON, D. E.

1884.—Geographical distribution of Southern cattle fever <In report of the Chief of the Bureau of Animal Industry. U. S. Comm. Agr., report, 1884, pp. 252–258, pls. 3.

Discusses occurrence of fever in Va., N. C., S. C., Ga., Tenn. Maps show limits east but not west of Mississippi River.

1904.—Relations of Federal Government to control of contagious diseases of animals <U. S. D. A., yearbook, 1903, pp. 491–506; pp. 505 et seq.

Deals with *Margaropus annulatus*.

SALMON, D. E., and THEOBALD SMITH.

1892.—Southern cattle fever (Texas fever) <U. S. D. A., Bur. A. I. special report on diseases of cattle and cattle feeding, pp. 428–438, pls. 42–44.

1904.—Texas fever, or Southern cattle fever <U. S. D. A., Bur. A. I., cir. 69, pp. 1–13. (Reprint from special report diseases of cattle, revised, 1904, by Salmon and Mohler.)

SALMON, D. E., and C. W. STILES.

1901.—The cattle ticks (Ixodoidea) of the United States <U. S. D. A., Bur. A. I., 17th ann. report, 1901, pp. 380–491, pls. 74–98, figs. 47–238.

This is a most valuable work, particularly rich in bibliographical references and illustrations. It is an absolute essential in the study of the ticks of this country.

SCHROEDER, E. C.

1900.—A note on the vitality of the Southern cattle tick <U. S. D. A., Bur. A. I., 16th ann. report, pp. 41–42.

SCHROEDER, E. C., and W. E. COTTON.

1900.—Growing noninfected ticks and afterwards infecting them <U. S. D. A., Bur. A. I., 16th ann. report, pp. 33–41.

SMITH, THEOBALD, and F. L. KILBORNE.

1893.—Investigations into the nature, causation, and prevention of Texas or Southern cattle féver <U. S. D. A., Bur. A. I., bul. 1, pp. 1–301, pls. 10, figs. 7.

This scholarly work demonstrated the transmission of fever by *Margaropus annulatus*. It suggests much of the work since done in the study of disease transmission by insects and ticks.

SMITH, T., F. L. KILBORNE and E. C. SCHROEDER.

1893.—Additional observations on Texas cattle fever <U. S. D. A., Bur. A. I., bul. 3, pp. 67–72.

VINCENHELLER, W. G.

1906.—The cattle tick in Washington and Benton counties <Ark. Agr. Exp. Sta., bul. 90, pp. 131–141.

WILLOUGHBY, C. L.

1904.—Cattle ticks and Texas fever; immunizing experiments in Georgia <Ga. Agr. Exp. Sta., bul. 64, pp. 143–182, figs. 9, August.

SECTION B.

RELATING TO FOREIGN DISEASE-TRANSMITTING TICKS.

BANKS, C. S.

1904.—The Australian tick (*Boophilus australis* Fuller) in the Philippine Islands <U. S. D. War, Bur. Govt. Laboratories, bul. 14 (Biological Laboratory, Div. Ent., bul. 2), pp. 13–21, figs. 16–23, pls. 9.

BRUCE, D.

1905.—The advance in our knowledge of the causation and methods of prevention of stock diseases in South Africa during the last ten years <Science, n. s., vol. 22, pp. 289–299 and 327–333.

EDINGTON, A.

1904.—Note on the co-relation of several diseases occurring among animals in South Africa <Agr. Journal Cape Good Hope, vol. 25, pp. 139–152.

FROGGATT, WALTER W.

1901.—The fowl tick (*Argas americanus* Packard) <Agr. Gazette N. S. Wales, vol. 12, pp. 1349–1352, pl.

FULLER, CLAUDE.

1896.—Ticks, a fowl-infesting tick (*Argas* sp.) <Agr. Gazette N. S. Wales, vol. 7, pp. 590–597 (reprint, pp. 1–8).

1896.—The bovine tick fever <Agr. Gazette N. S. Wales, vol. 7, pp. 760–787, pls. 1–5.

1899.—The common blue tick <Agr. Journal Cape Good Hope, vol. 14, pp. 363–369, March.

GRAY, C. E., and W. ROBERTSON.

1902.—Report upon Texas fever or redwater in Rhodesia <Argus Printing and Pub. Co., Ltd., Cape Town, pp. 27, pls. 22.

1902.—Redwater in Rhodesia <Agr. Journal Cape Good Hope, vol. 21, pp. 435–458, November.

HERRERA, A. L.

1905.—Las Parásitos del Ganado <Com. Parasit. Agricola., cir. 8, pp. 22–25, figs. 31–34.

HUNT, SIDNEY.

1898.—Tick fever <Queensland Agr. Journal, pp. 235–236.

HUTCHEON, D.

1900.—Redwater and its history <Agr. Journal Cape Good Hope, vol. 17, pp. 331–339, 395–409.

1900.—History of heartwater <Agr. Journal Cape Good Hope, vol. 17, pp. 410–417.

1903.—Virulent redwater in the Transvaal <Agr. Journal Cape Good Hope, vol. 23, no. 1, pp. 39–60.

JOBLING, J. W., and P. G. WOOLLEY.

1904.—Texas fever in the Philippine Islands and the Far East <U. S. D. War, Bur. Govt. Laboratories, bul. 14, pp. 5–11, pls. 15.

KOSSEL, H., A. WEBER, SCHÜTZ, and MIESSNER.

1903.—Ueber die Hämoglobinurie der Rinder in Deutschland <Arb. K. Gesundheitsamte, no. 1, pp. 1–77, pls. 3.

The blood parasite is the same as that of Texas fever. *Ixodes ricinus* (*reduvius*) acts as a transmitter.

LAHILLE, F.

1905.—Contribution à l'étude des Ixodidés de la République Argentine, pp. 1–166, pls. 1–13.

This paper contains a great deal on the biology of *Margaropus microplus*.

LIGNIÈRES, J.

1900.—La Tristeza ou Malaria bovine dans la République Argentine, pp. 1–172, pls. 14.

LOUNSBURY, C. P.

1899.—The bont tick *Amblyomma hebræum* Koch <Agr. Journal Cape Good Hope, vol. 15, pp. 728–743.

1900.—Life history of a tick <Ent. News, vol. 11, pp. 336–340, January.

Life history of *Amblyomma hebræum* Koch.

1900.—Tick-heartwater experiment <Agr. Journal Cape Good Hope, vol. 16, pp. 682–687.

1900.—Insect bites and the effects thereof <Can. Ent., vol. 32, pp. 17–24.

Argas and *Ornithodoros* spp.

1900.—Notes on some South African ticks <U. S. D. A., Bur. Ent., bul. 26, n. s., pp. 41–49.

1902.—Report of Government Entomologist for the Cape of Good Hope for 1901.

Includes "Tick heartwater investigations," pp. 29–73, pls. 4–6.

1903.—The fowl tick. Studies on its life cycle and habits <Rept. Agr. no. 20, pp. 1–15, pls. 3. Reprint Agr. Journal Cape Good Hope, September.

1903.—Report of the Government Entomologist for the Cape of Good Hope for 1902.

"Ticks and Rhodesian cattle disease," "Ticks and malignant jaundice," "Ticks and heartwater," pp. 16–41.

1903.—Ticks and African coast fever <Transvaal Agr. Journal, vol. 2, no. 5, pp. 4–13.

LOUNSBURY, C. P.—Continued.

1904.—External parasites of fowls <Reprinted from the Agr. Journal, pp. 7, November.

Relating to *Argas persicus*.

1904.—Persian sheep and heartwater <Agr. Journal Cape Good Hope, vol. 25, no. 2, pp. 175–186, figs. 3.

1904.—Distribution of coast fever ticks <Agr. Journal Cape Good Hope, vol. 25, no. 3, pp. 268–270, pl. 1.

The distribution of *Rhipicephalus appendiculatus*, *R. simus*, *R. evertsi*, and *R. capensis* is briefly outlined.

1904.—Transmission of African coast fever <Rept. Agr., no. 5, pp. 1–7, pls. 3. Reprint: Agr. Journal, Cape Good Hope, April.

1904.—Report of the Government Entomologist for the Cape of Good Hope for 1903.

Includes "ticks and malignant jaundice" and "ticks and heartwater," "ticks and South African coast fever," pp. 11–45, pls. 7

1905.—Tests of substances for tick destruction <Agr. Journal Cape Good Hope, vol. 26, pp. 387–395, March.

1905.—Report of the Government Entomologist for the Half Year ended June 30, 1904.

Contains a special report, "ticks and African coast fever," pp. 10–25.

MALLY, C. W.

1904.—Notes on the so-called paralysis tick, *Ixodes pilosus* <Agr. Journal Cape Good Hope, September. Reprint by Dept. of Agric., no. 17, 1904.

MARCHAUX, E., and A. SALIMBENI.

1903.—La Spirillose des Paules <Annals l'Institut Pasteur, vol. 17, pp. 569–580.

Spirillosis of chickens and other fowls transmitted by *Argas miniatus*.

MOTAS.

1903.—The rôle of ticks in the development of carceag <Compt. Rend. Soc. Biol., Paris, vol. 55, no. 14, pp. 501–504.

The writers have seen only a review of this paper in Experiment Station Record.

POUND, C. J.

1899.—Notes on the cattle tick. Its development, life history, habits, and geographical distribution <P. Soc. Queensland, vol. 14, pp. 28–38.

ROBERTSON, F. H.

1905.—Fowl tick experiments <Journ. Dept. Agr. West Australia, vol. 12, no. 6, pp. 561–563.

It was found that fowl ticks remain alive at least 2 years and 3 months without the presence of any fowls from which to derive nourishment. In these experiments the ticks were kept in small pill boxes which were practically air tight. In the nymph stage ticks may live for 2 months without food.

SCHMIDT, A.

1904.—The tick disease of cattle (hæmoglobinæmia ixodioplasmatica boum) in German and English East Africa and Uganda <Arch. Wiss. u. Prakt. Tierh., vol. 30, nos. 1–2, pp. 42–101.

The literature of this subject is discussed with references to a bibliography of 221 titles. We have not the original work at hand and refer to the translated title in the Experiment Station Record, XVI, p. 201.

STOCKMAN, STEWART.

1904.—Rhodesian redwater, vel East African coast fever, vel tropical piroplasmosis <Report of the Transvaal Dept. of Agric., 1903 to 1904, pp. 40–66.

Includes history of invasion and spread in Transvaal, permit-system, dipping, immunity, preventive inoculation, prevention and eradication, and transport experiments.

THEILER, A.

1903 and 1904.—The Rhodesian tick fever <Transvaal Agr. Journ., vol. 1 (1903), no. 4, pp. 93–110, pl. 1; vol. 2 (1904), no. 7, pp. 421–438, pl. 1.

1904.—The transmission of East Coast fever by ticks <Transvaal Agr. Journ., vol. 3, no. 9, pp. 71–86, October.

1905.—Further notes on piroplasmosis of the horse, mule, and donkey <Transvaal Agr. Journ., vol. 3, no. 12, pp. 706–716.

1906.—Transmission and inoculability of spirillosis in cattle <Transvaal Dept. Agr., ann. rept. Dir. Agr. 1904–1905, pp. 123–151.

The writer shows that the natural transmission of spirillosis is by the progeny of *Rhipicephalus decoloratus*, which have developed on cattle affected by spirillosis.

WHELER, E. G.

1899.—Louping ill and the grass tick <Journ. Royal Agr. Soc. England, ser. 3, vol. 10, pt. 4, pp. 626–644.

See note under following title.

1902.—Parasitically inoculated diseases <Trans. Highland and Agr. Soc. Scotland, ser. 5, vol. 14, pp. 16–35, figs. 2.

Surmises that "louping ill" is transmitted by *Ixodes ricinus*. Later investigations have negatived this.

SECTION C.

RELATING TO TRANSMISSION OF HUMAN DISEASE BY TICKS.

CHRISTY, CUTHBERT.

1903.—"Tick fever" in man <The Thompson Yates and Johnson Laboratories Report, vol. 5, n. s., part 1, pp. 187–189.

DUTTON, J. E., and J. L. TODD.

1905.—The nature of human tick fever in the eastern part of the Congo Free State, with notes on the distribution and bionomics of the tick <Liverpool School of Tropical Medicine, memoir 17, pp. 26.

Includes paper by Robert Newstead, "On the external anatomy of *Ornithodoros moubata* (Murray)."

KING, W. W.

1906.—Experimental transmission of Rocky Mountain spotted fever by means of the tick <U. S. T. D., Public Health and Marine-Hospital Service, Public Health Reports, vol. 21, pp. 863–864, July 27.

NEWSTEAD, R.

1905.—On the external anatomy of *Ornithodoros moubata* <Liverpool School of Tropical Medicine, memoir 17, pp. 21–26, November.

RICKETTS, H. T.

1906.—The study of "Rocky Mountain spotted fever" (tick fever?) by means of animal inoculations <Journ. Am. Med. Assn., vol. 47, pp. 33–36, July 7.

1906.—The transmission of Rocky Mountain spotted fever by the bite of the wood tick (*Dermacentor occidentalis*) <Journ. Am. Med. Assn., vol. 47, p. 358, August 4.

STILES, CH. W.

1905.—A zoological investigation into the cause, transmission, and source of Rocky Mountain "spotted fever" <U. S. T. D., Public Health and Marine-Hospital Service, Hygienic Laboratory, bul. 20, pp. 1–121.

SECTION D.

Relating to the Classification and Distribution of Ticks.

Banks, Nathan.

1895.—The Arachnida of Colorado <Ann. N. Y. Acad. Sci., vol. 8, pp. 417–434.

Dermacentor americanus L. and *Rhipicephalus* sp. are listed.

1899.—Reports upon the insects, spiders, mites, and myriapods collected on the Commander Islands Expedition (The fur seals and fur-seal islands of the North Pacific Ocean, pt. 4, pp. 328–351).

Lists *Ixodes borealis*, supposes *I fimbriatus* Kramer and Neumann to be the male.

1901.—Acarina in "Some spiders and other arachnida from southern Arizona" <Proc. U. S. Nat. Museum, vol. 23, p. 590.

Mentions *Argas sanchezi* Dugès from New Mexico and Arizona; also a species of Ixodes from Arizona.

1902.—Papers from the Hopkins-Stanford Galapagos Expedition, 1898–1899, vol. 7, Entomological Results (6). The Arachnida, Proc. Wash. Acad. Sci., vol. 4, p. 70, pl. 2, fig. 9.

Argas transversa, n. sp., and mention of *Amblyomma pilosum* Neum.

1902.—Some Arachnida from New Mexico <Proc. Acad. Nat. Sci. Phila., 1901, pp. 568–596.

Lists *Argas sanchezi* Neum., *Ixodes diversifossus* Neum., *Dermacentor reticulatus* Fab., *Margaropus* (*Boophilus*) *annulatus*.

1904.—The Arachnida of Florida <Proc. Acad. Nat. Sci. Phila., pp. 120–147.

Margaropus (*Boophilus*) *annulatus* Say, *Ixodes scapularis* Say, *Dermacentor variabilis* Say, *Amblyomma tuberculatum* Marx.

1904.—Some Arachnida from California <Proc. Cal. Acad. Sci., vol. 3, ser. 3, no. 13, pp. 331–369, pls. 38–41.

1904.—A treatise on the Acarina or mites <Proc. U. S. Nat. Museum, vol. 28, pp. 1–114.

Birula, A.

1895.—Ixodidæ novæ vel parum cognitæ Musei Zoologici Academiæ Cæsareæ Scientiarum Petropolitanæ <Bull. Acad. Imp. Sci. St. Petersbourg, ser. 5, vol. 2, no. 4, pp. 353–364, pls. 1–2.

Fitch, Asa.

1872.—Fourteenth report on the noxious, beneficial, and other insects of the State of New York, pp. 363–373.

Contains descriptions of the following species: *Ixodes americanus*, *quinquestriatus*, *robertsoni*, *cruciarius*, *Ixodes* (?) *odontalgiæ*.

Hassall, Albert.

1900.—Note on the chicken tick (*Argas americanus*) <U. S. D. A., Bur. A. I., 16th report, pp. 496–500, figs. 16–22, pl. 16.

Koch, C. L.

1847.—Uebersicht des Arachnidensystems, vol. IV, pp. 1–136, pls. 1–30.

Marx, George.

1893.—Note on the classification of the Ixodidæ <Proc. Ent. Soc. Wash., vol. 2, pp. 232–237.

Contains tables of North American genera.

1893.—On the morphology of the ticks <Proc. Ent. Soc. Wash., vol. 2, pp. 271–287.

1894.—Plate illustrating following species published in connection with obituary, Proc. Ent. Soc. Wash., vol. 3, pp. 195–201: *Rhynchoprium spinosum*, (=*Ornithodoros megnini*, nymph), *Ornithodoros americanus*, (=*O. megnini*, adult), *Argas americanus*.

MURRAY, ANDREW.

1877.—Economic entomology, Aptera, pp. 180–204.

Deals with the Ixodidæ.

NEUMANN, L. G.

1896.—Révision de la famille des Ixodidés, I <Mem. Soc. Zool. France, IX, pp. 1–44, figs. 1–36.

1897.—Révision de la famille des Ixodidés, II. Ixodinæ <Mem. Soc. Zool. France, vol. 10, pp. 324–420, figs. 1–45.

1899.—Révision de la famille des Ixodidés, III <Mem. Soc. Zool. France, vol. 12, pp. 107–294, 63 figs. in text.

1901.—Révision de la famille des Ixodidés, IV <Mem. Soc. Zool. France, vol. 14. pp. 249–372, 18 figs. in text.

This important monograph of the ticks of the world, unfortunately, is obtained only with considerable difficulty.

1902.—Notes sur les Ixodidés, I <Arch. Parasit., vol. 6, pp. 109–128, figs. 6.

1904.—Notes sur les Ixodidés, II <Arch. Parasit., vol. 8 (1904), no. 3, pp. 444–464, figs. 2.

1905.—Notes sur les Ixodidés, III <Arch. Parasit., vol. 9 (1904), no. 2, pp. 225–241.

NUTTALL, G. H. F.

1899.—The rôle of insects, arachnids, and myriapods as carriers of human and animal diseases which are produced by bacteria and animal parasites Hyg. Rundschau, vol. 9, no. 5, pp. 209–220; no. 6, pp. 275–289; no. 8, pp. 393–408; no. 10, pp. 503–520; no. 12, pp. 606–620.

OSBORN, H.

1896.—Insects affecting domestic animals <U. S. D. A., Div. Ent., bul. 5, n. s.

PACKARD, A. S., Jr.

1869.—List of hymenopterous and lepidopterous insects collected by the Smithsonian expedition to South America, under Prof. James Orton; appendix to report on Articulates. Ann. Rept. Peabody Academy of Science, pp. 1–14.

Contains descriptions of following new species of American forms: *Ixodes perpunctatus*, *unipunctata* (=*Amblyomma americanum*), *leporis-palustris* (*Hæmaphysalis*), *chordeilis*, *bovis* (=*Margaropus annulatus*), *bibronii*, *naponensis* (S. A.), *albipictus* (N. A.), *nigrolineatus*, *cookei*.

1873.—Descriptions of new insects. Arachnida <U. S. Geological Survey of Mont., Idaho, Wyo., Utah, 1872; pp. 740–741.

Includes *Ixodes bovis* Riley (= *Margaropus annulatus*) and *Argas americanus* n. sp., with figures of each.

RILEY, C. V.

1893.—Report on a small collection of insects made during the Death Valley Expedition <U. S. D. A., Biol. Surv., N. A. Fauna, no. 7, Part II, p. 252.

Lists seven species of Ixodidæ—determined by Doctor Marx.

SALMON, D. E., and CH. W. STILES.

1901.—See above.

SAY, THOMAS.

1821.—An account of the arachnides of the United States <Journ. Acad. Nat. Sci., vol. 2, pp. 59–83; Leconte edition, vol. 2, pp. 9–24.

Descriptions of the following species of Ixodes: *annulatus* (*Margaropus*), *erraticus*, *scapularis*, *orbiculatus* (=*Amblyomma americanum?*), *variabilis* (*Dermacentor*), *fuscous* (*fuscus*), *crenatum* (=*Amblyomma cajennense*), *punctulatus* (=*Dermacentor variabilis?*).

Stoll, Otto.

1886–1893.—Arachnida Acaridea <Biol. Cent.-Am., pp. 18–24, pls. 12–14.
Five species are discussed.

Ward, Henry B.

1899.—The ticks of Nebraska <Nebraska State Board of Agriculture, annual report for 1899, pp. 193–205. Reprint: Studies from the Zoological Laboratory, no. 38.

Wheler, E. G.

1906.—British ticks <Journ. Agr. Sci., vol. 1, pp. 400–429, pls. 5–10.

Williams, S. R.

1905.—Anatomy of *Boophilus annulatus* Say <Proc. Boston Soc. Nat. Hist., vol. 32, pp. 313–334, pls. 18–22.

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